Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2007-07

STRATEGIES FOR WATER RECLAMATION: THE ROLE OF POLICY AND TECHNOLOGY IN THE LAS VEGAS WATER SUPPLY

Final Report – ESD.10 Introduction to Technology and Policy

Anna N. Allen
Christopher W. Evans
Tarek Rached
Hsin Min Wong

Massachusetts Institute of Technology
Technology and Policy Program

January 2007

Strategies for Water Reclamation: The Role of Policy and Technology in the Las Vegas Water Supply

Final Term Project Report
ESD 10 Introduction to Technology and Policy
December 7, 2006

Prepared by:
Anna N. Allen
Christopher W. Evans
Tarek Rached
Hsin Min Wong

Preface

This report presents the results of a graduate student final term project in the course ESD.10: *Introduction to Technology and Policy* through the Technology and Policy Program at the Massachusetts Institute of Technology.

Report committee members include:

Anna N. Allen: *anna@mit.edu*

Christopher W. Evans: *cevans@mit.edu*

Tarek Rached: *tarekr@mit.edu*

Hsin Min Wong: *hsinmin@mit.edu*

Acknowledgements

The committee wishes to thank those who provided comments that assisted in development of this report, which seeks to analyze the technology and policy interactions resulting from water reclamation and reuse in Las Vegas, Nevada. The committee specifically wishes to express its appreciation to the following experts and individuals who offered comment on the report:

Dr. Stephen Parker, Director, Water Science and Technology Board, National Research Council

Dr. Henry Venema, Director, International Institute of Sustainable Development

Dr. Chanathip Pharino, Post-Doctoral Associate, MIT Sea Grant

Mr. Gary Grinnell, Senior Civil Engineer, Las Vegas Valley Water District

Ms. Danielle Adams, Teaching Assistant, ESD.10: *Introduction to Technology and Policy*

Executive Summary

The goals of this report are to: (i) consider Las Vegas' current water reclamation and reuse strategies using a case study framework to examine policy and reclamation technology issues in urban areas; and (ii) using this case study, develop general recommendations and best practices to guide the implementation of water reclamation technologies in the U.S. To accomplish these goals, the committee assessed: (i) the state of the art in water reclamation; (ii) how water management issues and the role of water reclamation are framed in Las Vegas; (iii) the perspectives and alignment of different groups of stakeholders involved in water management issues; and (iv) reclamation technology and policy interactions with respect to public perception, health, environment, regulation and incentives, and security issues.

Securing access to quality potable and non-potable water sources is a topic of increasing international and domestic concern due to growing population needs, urbanization, and changing climate. Many cities currently approaching the limits of their available water sources are exploring options for extending their water resources through other means. One approach to alleviating water shortages involves reducing demand for potable water by utilizing treated, reclaimed wastewater for non-potable purposes, such as landscape irrigation.

In 2003, the Department of the Interior launched its Water 2025 report, identifying Las Vegas as one of the six cities facing "chronic water supply problems in the West" (Bureau of Reclamation, 2003). Given its location in a water constrained area, coupled with a primary reliance on its allocated 5% of the Colorado River water, Las Vegas faces unique challenges in securing a safe, reliable water supply into the future (SNWA, 2006a). Las Vegas' water problem is exacerbated by large population growth amidst its worst drought in history (SNWA, 2006d; City of Las Vegas, 2006c). At the same time, the city is among the cleanest producers of reclaimed water in the U.S., and is engaging in innovative solutions to secure additional resources through negotiations with neighboring states, and the development of additional groundwater and surface water resources (CWC, 2006a; SNWA, 2006a). Las Vegas is implementing water reclamation as one of a number of extensive water conservation measures to manage its demand for potable water.

Las Vegas is currently discharging most of its highly treated effluent to Lake Mead for "return flow credits," a practice which ultimately enables increased withdrawals from the Colorado River but creates unplanned indirect reuse of potable water. Additionally, reclamation is helping offset potable water demands via Las Vegas' combined system of water reclamation facilities (SNWA, 2006a). These include centralized facilities and smaller decentralized treatment plants that directly supply non-potable reclaimed water to golf courses and other large point source users, as well as on-site water reclamation systems used by smaller-scale point source users such as hotels and resorts (CCWRD, 2006a; 2006d; City of Las Vegas, 2006a; 2006b; KUED, 2006). As Las Vegas develops its in-state water resources, which are not eligible for return flow credits, such direct non-potable water reuse will further increase in importance. Within this context, the committee has chosen to examine Las Vegas' water reclamation and reuse strategy in greater detail.

The new contributions of this report include:

- Providing an analysis of wastewater reclamation and reuse policies using a case study framework and applying them to a large U.S. city, Las Vegas;
- Applying wastewater technology and policy issues considered in previous NRC reports and U.S. wastewater reuse studies;
- Extrapolating specific best practices from the Las Vegas case study to guide implementation in other communities considering reclamation strategies; and
- Developing recommendations on wastewater reclamation for application at the national level.

From the Las Vegas case study, the committee also developed a set of generalized best practices when for states and municipalities to consider when implementing water reclamation projects in the U.S., outlined below.

<u>Best Practices in Implementing Water Reclamation and Reuse Projects</u>

1) Issue framing is critical in developing successful wastewater reclamation and reuse programs and should be given specific attention through a formalized process.

2) Identify stakeholders and involve them early in the decision-making process.

3) Conduct extensive public education, with transparency in the dissemination of information on the benefits and risks associated with water reclamation projects.

4) Develop an incentive-based framework to promote wastewater reuse.

5) Consider the implementation of a combination of different wastewater reclamation and reuse systems based on specific demand requirements from end-users.

6) Implement environmental management systems, such as EMS under ISO 14000 to quantify, manage, and mitigate environmental risks associated with water reclamation practices.

Based on the findings of the Las Vegas case study, the committee recommends the following:

- **The establishment of an entity within the EPA to work closely with states and local municipalities to advance and support wastewater reclamation.** This entity will provide a comprehensive service for local agencies considering the implementation or expansion of wastewater reclamation projects. In addition to serving as a clearinghouse on current regulatory, technological, health, and environmental considerations in wastewater reclamation, this entity will work with relevant authorities to establish or review national policies, guidelines, and strategies to advance efforts in wastewater reclamation.

- **The development and coordination of guidelines by EPA for state and municipal wastewater treatment and distribution regulations organized by non-potable end use to address any analysis gaps.** The EPA should work closely with states and municipalities to establish uniform design, construction, operation, and maintenance guidelines to minimize variability in program implementation and processes. These guidelines, if adopted, can help a state organize its utilities treatment and distribution systems by unifying the fragmented requirements of local, state, and federal regulation. Given the variability of current wastewater programs and the level of treatment discrepancies between states and municipalities, integration of wastewater system guidelines should occur on a federal level to insure wastewater treatment and distribution components are standardized through regulation.

- **The development of a Health Management System framework to facilitate control, auditing, and the quantification of uncertain health risks in water reclamation.** Although management systems are not sufficient to guarantee public safety, a comprehensive framework for control and assessment can help mitigate serious health risks. These systems should, at minimum, include preliminary risk assessment, water quality monitoring, health and safety testing, and the evaluation of overall system reliability (NRC, 1998: 3).

In addition, the committee recommends the following areas for further research:

- **The tools and frameworks to evaluate the efficacy of a flexible combination of wastewater reclamation and reuse systems need to be developed.** The development of integrated, consistent metrics pertaining to the efficiency and effectiveness of combination of different wastewater reclamation systems (centralized, decentralized and on-site) as a whole, is important towards investment decisions in new water reclamation infrastructure as well as in determining how well existing systems are performing. These metrics need to encompass the system as a whole, from the sources of wastewater, through treatment, all the way to distribution and end use.

- **There is an urgent need for further research on water quality monitoring and treatment, specifically with regards to: (i) estimating risks to health and the environment, (ii) the long term health effects of contaminants in reclaimed water, (iii) detection and monitoring of pathogen levels in reclaimed water, and (iv) methods for assessing and improving water reclamation system reliability.** Despite the effectiveness of advanced water treatment processes, there are inherent uncertainties in the effectiveness and reliability of these systems. As a result, further research is essential in mitigating the risks to human health posed by indirect reuse of potable water.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

AWWA – American Water Works Association
BMI – Basic Management, Incorporated
CCBC – Clark County Board of Commissioners
CCWRD – Clark County Water Reclamation District
CRC – Colorado River Compact
CWA – Clean Water Act
CWC – Clean Water Coalition
CWC-CAC – Clean Water Coalition Citizen's Advisory Committee
EMP – Effluent Management Plans
EMS – Environmental Management System
EPA – Environmental Protection Agency
FOIA – Freedom of Information Act
ISO – International Standards Organization
LVVWD – Las Vegas Valley Water District
LVWWC – Las Vegas Wash Coordination Committee
NAC – Nevada Administrative Codes
NBP – National Biosolids Partnership
NDEP – Nevada Division of Environmental Protection
NDWR – Nevada Division of Water Resources
NIMBY – Not In My Backyard
NRC – National Research Council
MGD – Million Gallons per Day
SNWA – Southern Nevada Water Authority
UV – Ultraviolet

1

Introduction

1.1 Motivation

Securing access to quality potable and non-potable water sources is a topic of increasing international and domestic concern due to growing population needs, urbanization, and changing climate. Many cities currently approaching the limits of their available water sources are exploring options for extending their water resources through other means. One approach to alleviating water shortages involves reducing demand for potable water by utilizing treated, reclaimed wastewater for non-potable purposes, such as landscape irrigation, toilet flushing, and environmental enhancement. Offsets in potable water can be implemented at the municipal level either by encouraging local, on-site wastewater reclamation or providing centralized or decentralized dual-distribution systems.

Wastewater reclamation and reuse projects produce many benefits when incorporated into a larger water management strategy, including alleviating demand burdens on municipal water sources and decreasing negative environmental impacts. However, these projects are most appropriate in places where access to water is hampered by environmental constraints and may not be suitable in areas with substantial water availability.

1.2 Context

In 2003, the Department of the Interior launched its *Water 2025* report, which identified "chronic water supply problems in the West" as "one of the greatest challenges facing the nation in coming decades" (Bureau of Reclamation, 2003). In particular, the study identified the City of Las Vegas, along with six others, as a place of conflict over available water resources during the next two decades. At the same time, Las Vegas is a city with a rich and colorful history that is closely connected with innovative, state of the art development of the West's water resources. The city draws water from Lake Mead, a reservoir formed by the redoubtable Hoover Dam that commands the Colorado River, one of the most important rivers in the Western United States. At the same time, advanced sewage treatment plants in the city produce some of the cleanest water in the country.

Currently, Las Vegas is struggling to meet its growing water demand using Lake Mead and is looking at alternative approaches to augment its water supply. These approaches include Colorado River transfers, tapping of groundwater and surface water sources in neighboring counties, and water conservation, including water reclamation. Each strategy has its merits and limitations. The committee chose to examine water reclamation in detail, and it is within this context that the authors analyzed the state of water reclamation and issues around its implementation in Las Vegas.

1.3 Goals of this Report

The goal of this report is to use Las Vegas as a case study to examine policy and technology issues around water reclamation in urban areas to develop general recommendations and best practices to guide the implementation of water reclamation technologies in the U.S. Specifically, the report aims to consider the following:

- The state of the art in water reclamation;
- Policy issues around wastewater reclamation, their interactions with technology, and how such interactions can enable or constrain water reclamation; and
- Best practices or gaps learned from Las Vegas that can be generalized for the U.S.

Section 2 summarizes the current state of water sources as well as wastewater sources, reuse applications, strategies, and distribution considerations. Section 3 provides a framework for analyzing technology and policy interactions in water reclamation, and Section 4 examines stakeholders affected by wastewater reclamation and reuse. Section 5 discusses various policy issues (public perception, health, environment, regulations and incentives, security) around wastewater reclamation and how technology and policy interact to promote or impede wastewater reuse. Section 6 uses the previous analysis to provide recommendations and best practices around water reclamation strategies in the U.S. in general. Section 7 provides potential areas for future research.

This report has *not* included an economic analysis of the full range of costs, benefits and potential risks associated with wastewater reuse. Such an analysis is important to evaluate the financial feasibility of water reclamation projects, as well as to assess the distribution of costs and benefits to facilitate the development of an equitable framework for cost recovery (WRF, 2006), and is worthy of a separate study.

1.4 New Contribution

There have been several international case studies on water reclamation and reuse where political, geographic, environmental and economic factors cause limited access to water resources (Bazza, 2003, Okun 2002, Onn 2005). In the U.S., the National Research Council (NRC) has conducted several authoritative studies on water reclamation and reuse. This report builds on the existing body of work developed by the NRC. The Council's seminal report, *Quality Criteria for Water Reuse* (1982), determined quality criteria for the potable use of reclaimed water, and established the concept that "drinking water should be obtained from the best quality source available" (NRC, 1982).

More recently, a 1998 report entitled *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water*, revisited a 1982 study amid growing demand for water supplies, and considered the availability of new technologies and information on water reclamation. It found that indirect potable reuse of water was a "viable application of reclaimed water," but recommended it be used as a last resource measure alongside a "project-specific assessment that includes contaminant monitoring, health and safety testing, and system reliability evaluation" (NRC, 1998: 3).

In addition to these two major reports on water reclamation and reuse issues, the NRC has produced related reports on the use of treated municipal wastewater for artificial recharge of aquifers (NRC, 1994), the use of reclaimed water in food production (NRC, 1996), and watershed management strategies for potable water supply in New York City (NRC, 2000).

This report seeks to support this existing work by assessing the current state of wastewater management in Las Vegas by analyzing pertinent policy issues in wastewater reclamation and reuse. Using specific policy issues identified in past U.S. studies, a framework is developed to integrate these issues in the larger context of a case study.

This type of case study analysis — considering the policy and technology interactions around water reclamation — has not been undertaken by the NRC in the past. By considering what Las Vegas has done well in wastewater reclamation and reuse projects, how the city has applied these technologies, and what could be improved, generalized lesson and practices can be drawn about wastewater best practices and action items can be recommended at the national level.

The new contributions of this report include:

- An analysis of wastewater reclamation and reuse policies using a case study framework and applying them to a large U.S. city, Las Vegas;
- Application of technology and policy issues considered in previous NRC reports and U.S. wastewater reuse studies;
- The extrapolation of specific best practices from the Las Vegas case study to guide implementation in other communities considering reclamation strategies; and
- Development of recommendations on wastewater reclamation for application at the national level.

2

Current State of Water Resources

Las Vegas is currently exploring a variety of options to meet its projected water demand. This section outlines the existing portfolio of water resources used by Las Vegas and then examines future efforts to diversify water resources given increasing projected demand. One of these strategies, wastewater reclamation and reuse, is then introduced and the technologies available in this area explained. Finally, a more in-depth study of Las Vegas' plan in implementing a variety of wastewater reuse and reclamation technologies is described.

2.1 Background

The history of water use in Las Vegas is characterized by limited access to water resources and a lack of infrastructure to distribute water to a rapidly growing population. While original reliance on groundwater sources successfully met water demand in the past, the expanding area eventually developed a need to utilize water from the Colorado River. Presented with challenges around providing river water, the federal government has at times intervened to finance public works projects such as the Hoover Dam and Las Vegas' current water system. Today, water supply continues to be constrained by exponential population growth and limited access to water resources, including the Colorado River. (Refer to Appendix 1 for details on the history of Las Vegas' water supply.)

Southern Nevada Water Authority (SNWA)

The Southern Nevada Water Authority (SNWA) is a seven-member agency formed in 1991 to consider water issues on a regional basis. It is comprised of the cities of Las Vegas, North Las Vegas, Henderson, Boulder City, the Big Bend Water District, the Clark County Water Reclamation District (CCWRD) and the Las Vegas Valley Water District (LVVWD), and is responsible for identifying, acquiring, and managing Southern Nevada water resources (SNWA, 2006a).

2.2 Existing Water Resources

Nearly 90% of Southern Nevada's drinking water comes from the Colorado River via Lake Mead. The rest comes from deep groundwater sources beneath the Las Vegas Valley, and a portion of reclaimed water that is mainly utilized for non-potable irrigation (SNWA, 2006a, 2006b, 2006c). The City of Las Vegas is supplied by these same three sources of water.

Colorado River

The Colorado River is the water source for more than 25 million people in seven states and Mexico. Its water is shared by the upper basin states of Colorado, New Mexico, Utah and

Wyoming, as well as the lower basin states of Arizona, California and Nevada (see Figure 1). Nevada is apportioned a mere 4.5%, or 300,000 acre-feet a year, of Colorado River's average annual flows under the Colorado River Compact (CRC), an allocation agreement drawn up in 1922[1] (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c).

In addition to its annual Colorado River water allotment, Nevada can potentially receive a share of "surplus" water in years when the river exceeds its average annual flows. However, the Colorado River is currently facing the worst drought situation in history. Lake Mead's water level has dropped approximately 70 feet since January 2000, reducing the availability of surplus water. Consequently, Southern Nevada is currently under a "Drought Alert" status (the third level out of a four level drought classification system), which increases the urgency to consider alternative non-Colorado water sources to augment Nevada's water supply (SNWA, 2006d).

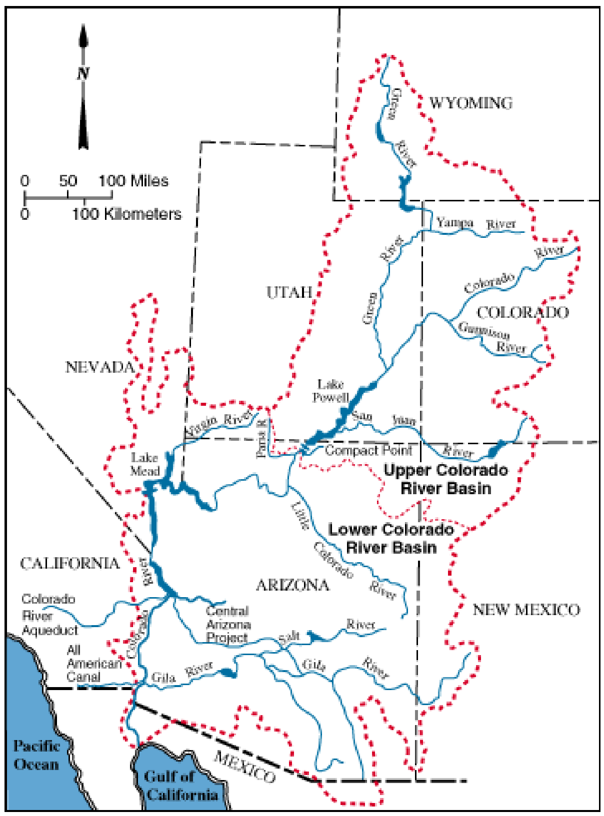


Figure 1: The Colorado River watershed in the Western United States (Bureau of Reclamation, 2006a)

Groundwater

Groundwater in the Las Vegas Valley supplies about 10%, or 43,000 acre-feet per year, of Southern Nevada's water supply. This ground water comes from three major aquifers located 300 to 1,500 feet underground. Groundwater is primarily used during the summer, when water demand is at its peak in the Las Vegas (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c).

[1] Such a low apportionment was based on agricultural needs back in 1922 when the compact was drawn up, which did not take into account future growth, and certainly not Las Vegas' dramatic urbanization since then.

Reclaimed Water

Nevada's annual withdrawal allotment from the Colorado River is on a "net consumptive" basis. Accordingly, when Nevada returns water to the Colorado River, it is considered a "return flow credit," and allows additional withdrawals equal to the amount of returned water. Hence, Nevada's net consumptive allotment is the amount of water it initially withdraws, minus the amount it returns to the Colorado River. Only water originally withdrawn from the Colorado River may count towards this return flow credit. For example, groundwater from the Las Vegas Valley or from other non-Colorado River sources returned to Lake Mead does not generate return flow credits. Nevada currently recycles all wastewater, returning 88% to the Colorado River as return flow credits and distributing the balance for direct non-potable reuse. The total size of Nevada's water resource pie is fixed, regardless of the proportion of wastewater reused versus the amount returned to the Colorado River for return flow credits, as shown by Figure 2 (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c).

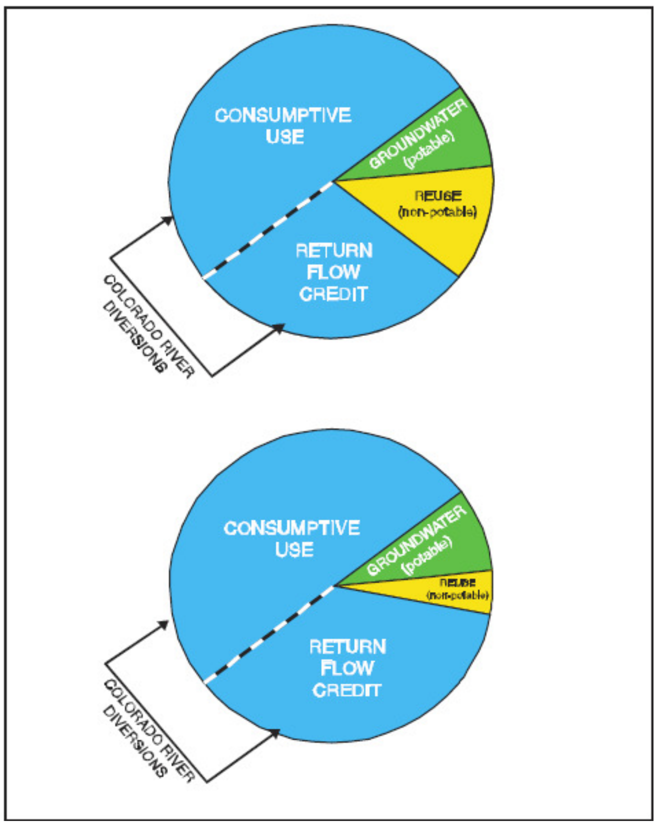


Figure 2: Southern Nevada's total water resource pie (SNWA, 2006a: 33)

2.3 Future Water Demand Estimates

Both population growth and future conservation estimates affect projected water demand in Las Vegas. In 2005, Las Vegas' population was over 1.7 million people and has increased by 5,000 to 7,000 people per month for the past ten years (City of Las Vegas, 2006c). On average, water supply resources are approximately 650,000 acre-feet (8.02 x 108 m^3) per year (Stave, 2003). Demand for water is projected to exceed the available water supply in 2025, as illustrated by Figure 3. These demand estimates provide important information used by the SNWA to develop its water management strategy of conservation and development of additional water resources.

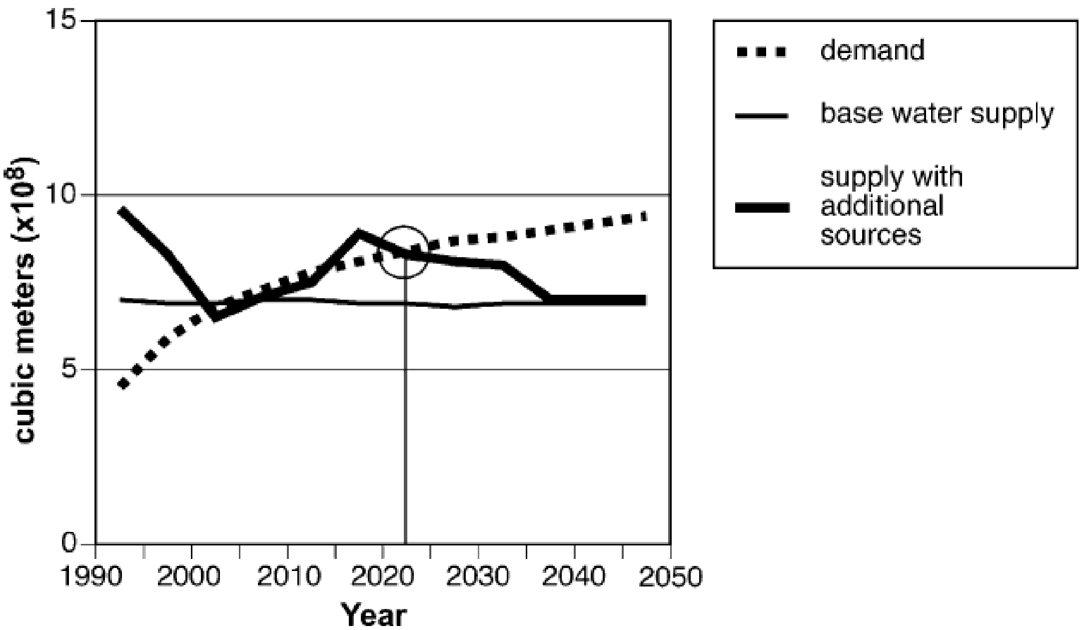


Figure 3: Metropolitan water supply and demand in Nevada (Stave, 2003)

2.4 Future Water Resource Options

Given limitations on Nevada's current water supply sources, the SNWA has identified three main measures to augment existing resources (SNWA, 2006a: 21-36):

i) Offsetting neighboring states' withdrawals from the Colorado River;
ii) Groundwater and surface water development; and
iii) Water conservation measures.

Colorado River Exchanges

One way Nevada can increase its withdrawal allotment from the Colorado River is by paying neighboring states to withdraw water from sources outside of the River. For instance, in 2004 the SNWA signed an agreement stipulating that Arizona will bank surplus water withdrawals from the Colorado River in a groundwater aquifer for Southern Nevada's future use.[2] Alternatively, the SNWA can pay coastal states such as California to build desalination plants to offset their withdrawals from the Colorado River (SNWA, 2006a).

Groundwater and Surface Water Development

Starting in 1998, the SNWA has embarked on projects to acquire groundwater rights of about 9,000 acre-feet per year from Clark County's Coyote Spring Valley. Southern Nevada is also looking into tapping aquifers in other regions of central and eastern Nevada.[3] Studies conducted have shown that there is enough water to serve local communities and supplement Southern Nevada's water resources without adverse effects to the environment (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c). It is reported that the pipelines needed to extract and deliver groundwater to South Nevada could cost up to $12 billion (Roessler, 2006: 19).

Water Conservation

Water conservation provides another alternative to augmenting Nevada's water supply from the demand management perspective. Currently, outdoor water use accounts for about 70% of residential water use (SNWA, 2006b), and conservation efforts have largely focused on landscape irrigation. Measures include turf restrictions for residential and commercial properties, assigned watering days and increased penalties for water waste. In addition, a multi-tiered water pricing structure is in effect to promote conservation (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c).

Water Reclamation

Wastewater reclamation forms an important component of Nevada's water conservation strategy. As described earlier, Southern Nevada reclaims 100% of its wastewater, most of which is returned to Lake Mead and contributes to an increased water allotment for Nevada under the return flow credit scheme. This means that wastewater flowing from homes and businesses into the sewage system is "renewed" and does not contribute to a net water use. Only water not captured by the municipal sewage system, mainly that used for outdoor irrigation, is unrecoverable (SNWA, 2006a; SNWA, 2006b; SNWA, 2006c).

As the SNWA develops new in-state, non-Colorado River water resources, it is also exploring opportunities to receive credit for other sources of treated wastewater returned to Lake Mead. This treated wastewater could also be directly reused as a cost-effective measure to augment water supply in Southern Nevada. With the expected future increase in the use of non-Colorado

[2] When Southern Nevada wants to "withdraw" this saved water, Arizona will use the banked water, and Southern Nevada will withdraw the equivalent amount of Arizona's share of the Colorado River.

[3] Some planned projects include the Three Lakes Valley project (8,900 acre-feet per year of water from Three Lakes and Tikaboo valleys, expected to be completed after 2008) and the Clark, Lincoln and White Pine Counties project (125,000 to 200,000 acre-feet of water per year, expected to be completed after 2014). In terms of surface water development, the SNWA plans to divert 113,000 acre-feet per year and 7000 acre-feet per year of water from Virgin River and Muddy River, respectively.

River resources to cope with mounting water demands, the region is exploring greater opportunities for wastewater reuse in non-potable applications (SNWA, 2006a).

Benefits and Risks of Various Water Resource Options

Table 1 illustrates the benefits and risks of the main water resource options currently pursued in Las Vegas. The Las Vegas region is actively incorporating all of these options in their water management plan given the dire forecast of demand exceeding supply. Each option exhibits various health, environmental, security, and economic uncertainties that warrant careful consideration when determining an optimal water management strategy for Las Vegas. While each approach can be incorporated into a larger water management strategy, this report solely focuses on the policies and technologies surrounding wastewater reclamation and reuse systems.[4]

Table 1: Benefits and Risks of Water Resource Options

WATER RESOURCE OPTION	BENEFITS	RISKS
Banking: Colorado River surplus withdrawal contract with Arizona	Water not immediately needed can be saved for periods of drought or increased demand	Nature of banking not well understood; exact amounts of banked water may not be available in the future Arizona's obligation to Nevada might not always be met with banked water Interstate dependencies leads to less water security, increased risk of disputes (Gelt, 2004)
Desalination: Colorado River surplus withdrawal contract with California	Greater protection of high-quality groundwater due to reduced pumping of aquifers	Disposal of leftover salt Inadvertently capturing fish in coastal water intakes (McNulty, 2005) Water security depends on another state Interstate dependencies leads to less water security, increased risk of disputes (Gelt, 2004)
Groundwater and surface water exploration	Increase flows to Las Vegas Wash and Lake Mead Meet long term demand requirements	Degradation of neighboring counties' surface and groundwater Estimates of available groundwater may not be accurate Economic risks due to uncertain infrastructure investments Increased security risks around protecting extensive pipeline infrastructure Short term demand needs are not met
Outdoor and indoor water conservation	Less depletion of local aquifers, benefits to water-dependent ecosystems Reduced Wash erosion Overall drought relief Implementation is immediate No large infrastructure investments	Experts are more familiar with quantifying supply-side risks; less rules of thumb exist for demand-side savings (Ruzicka, 1996)

[4] As stated in Section 1, the focus of this report is not to justify the choice of water reclamation as a water resource option as opposed to other available options; rather it is to examine the issues around water reclamation *given* that it is a chosen water resource option.

2.5 Wastewater Sources and Applications

Sources

Wastewater can be broken down into three categories:

- Sewage: Sewage, also known as black water, comprised of human bodily waste or the outflow from industrial processes. It is collected and treated under federal and state regulations at water treatment facilities, after which it is discharged into the environment.
- Greywater: Greywater is produced from bathing, washing dishes and clothes, and kitchen water; it accounts for the majority of residential wastewater.
- Storm water: Storm water is the run-off from rainfall in urban areas, including roads, roofs, and sidewalks.

All three types of water are subject to varying degrees of contamination and require different levels of treatment depending on final use (Ludwig, 2006).

Types of Reuse

Water reuse can be divided into three categories:

- Potable / non-potable: Potable water is fit for human consumption with no further treatment, while non-potable water is not acceptable for human consumption.
- Direct / indirect: Direct reuse takes place when water leaving the treatment facility is conveyed without interruption to its end-use destination. This contrasts with indirect reuse, which occurs when treated effluent is first released in a larger body of water such as a waterway or an aquifer, from which it is later drawn and retreated for use.
- Planned / unplanned: Unplanned indirect reuse occurs when treated wastewater is unintentionally discharged into a body of water used as an intake for potable water treatment plan. As water officials become aware of wastewater in their inflow, they can plan for water reuse, which generally involves extra treatment and monitoring to mitigate the effects of wastewater inflow (Yari, 2005).

Intentional reclamation of treated wastewater in the U.S. is exclusively for direct non-potable end-use (NRC, 1998). Direct potable reuse does not occur in the U.S. In Las Vegas, reclaimed wastewater is currently returned to Lake Mead via the Las Vegas Wash, upstream of the city's intake facilities that draw water for potable treatment. In this way, Las Vegas practices unplanned indirect potable reuse by unintentionally drawing water for potable treatment from the same reservoir that receives its treated, reclaimed water.

Reuse Applications

Describing the final application of reclaimed water is essential in determining a suitable level of treatment needed to ensure safe water exposure. Different categories of reclaimed water end-use include:

- Urban: Landscape irrigation, fire protection, toilet flushing;
- Agricultural: Irrigation of food and non-food crops;
- Recreational: Fishing and boating;
- Environmental: Sustaining river flows and creating or enhancing wetlands; and
- Industrial: Power plants, cooling towers.

2.6 Treatment Considerations

As specified by the 2004 Environmental Protection Agency (EPA) "Guidelines for Water Reuse," there are three main levels of treatment available to wastewater (EPA, 2004):

- Primary. Primary treatment involves grit removal, screening, grinding, and sedimentation,
- Secondary. Secondary treatment includes oxidation of dissolved organic matter.
- Tertiary. Tertiary, or advanced treatment, entails advanced methods of nitrogen and phosphorus removal, granular filtration, and activation carbon absorption.

Disinfection is usually the last step for each of these treatment levels, using either chlorine or ultraviolet (UV) radiation to kill all biological contaminants (EPA, 2004: 171). The degree of treatment necessary for wastewater depends on the final use of water and the potential level of human exposure (EPA, 2004). While there are national suggested guidelines for treatment levels organized by end-use, there is a wide degree of treatment variability among states currently using reclaimed water (EPA, 2004: 139).

For reuse applications that involve irrigation, the presence of chlorides in the reclaimed water has a toxic effect on plants and crops, so most treatment facilities have converted to using UV treatment measures.[5] Another consideration in treatment of wastewater for irrigation or agricultural purposes is that nitrogen and phosphorus are actually beneficial to plant growth and therefore may not warrant complete removal in the treatment process (EPA, 2004).

[5] UV treatment also poses less of a security risk than chlorination because a malevolent act to release chlorine gas from treatment plants can have serious consequences.

Water Treatment in Las Vegas

Wastewater treatment facilities in the Las Vegas Valley are among the most advanced in the US. The quality of the treated effluent is in the top 7% of wastewater treatment facilities in the US. Only one other region, Scottsdale, Arizona, has the same high standard of treatment, as shown by Figure 4 (CWC, 2006a).

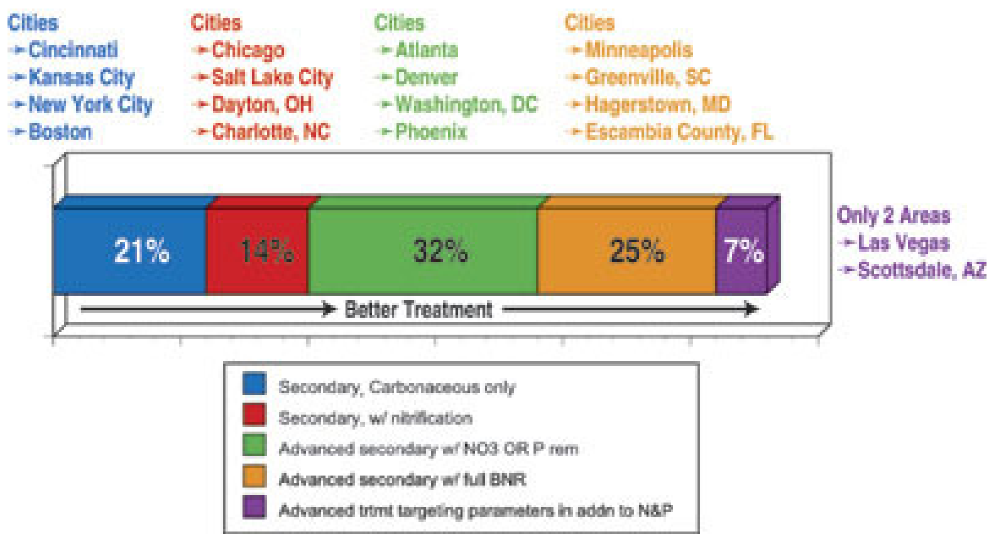


Figure 4: Levels of wastewater treatment in the U.S. (CWC, 2006a)

2.7 Distribution Considerations

A water distribution system includes all components and subcomponents necessary for the distribution of water by means of piping networks, control valves, storage tanks, and pumping station (Mays, 2000). In addition to providing potable water, these systems also supply water for non-potable uses such as fire control, landscape and agricultural irrigation.

Dual-distribution systems

Both decentralized and centralized water systems can be converted to a dual-distribution system, which utilizes two dedicated pipe networks to separately convey potable and non-potable water. Although dual-distribution systems require the same technical considerations as traditional potable water distribution systems around pumping, storing and delivering water, there are several factors to take into consideration when designing a dual-distribution network (EPA, 2004). Golf courses, parks and other outdoor irrigation are the primary potential target customers in Las Vegas of dual-distribution systems, comprising roughly 48% of total water demand (Stave, 2003).

If non-potable water is to be used for fire control or industrial use generally, large pipes must be used to meet maximum water demand requirements. The pipes for potable water can be much smaller than in a single distribution system, as potable water constitutes a minor fraction of total water demand (EPA, 2004).

Regulatory guidelines concerning the physical infrastructure of a dual system, such as minimum horizontal and vertical separation between potable and non-potable pipes, backflow and cross-contamination countermeasures should be heeded to protect potable water integrity. Pipes must also be clearly labeled and color-coded to differentiate between potable and non-potable lines and appropriate signs posted when reclaimed water is used in public areas (EPA 2004:10).

2.8 Wastewater Reclamation Systems in Las Vegas

This section explores Las Vegas' current efforts in wastewater reclamation, grouped by system scale: centralized, decentralized, and on-site. Selection of the reclamation and distribution scale depends highly on factors such as demand (e.g. volume and customer dispersion) for reclaimed water, proximity to the wastewater facility and end-use application of water. Based on these considerations, Las Vegas is pursuing a combination of centralized, decentralized and on-site approaches in implementing its wastewater reclamation and reuse projects (see Figure 5).

Scale of Reclamation

There are several ways to reclaim water in a city, broadly grouped into three approaches by their scale:

- <u>Centralized</u>: The largest scale approach includes centralized water systems, which transport water for an entire urban area and may involve reclaiming and distributing effluent throughout the same region.
- <u>Decentralized</u>: Decentralized systems are mid-range in scale and collect, treat, and distribute water from a region within a larger municipal area usually organized by consumer clusters with similar water requirements.
- <u>On-site</u>: The smallest method scale is on-site collection and treatment of water, which is restricted to an individual or small group of users who reclaim and reuse water in a localized, self-contained system.

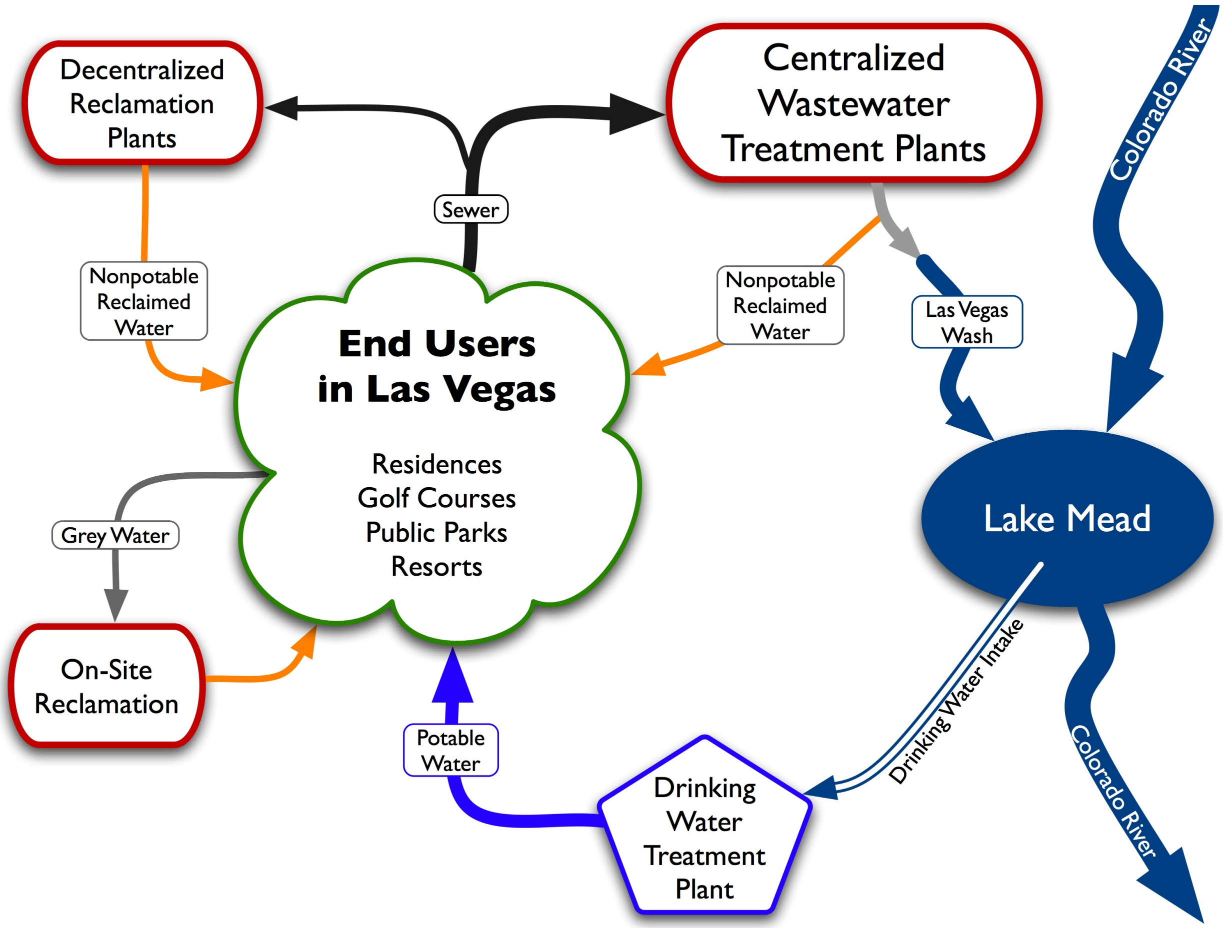


Figure 5: Abstract Map of the Las Vegas Water System, showing the various ways water reclamation technologies are being used to reduce the demand for potable water. A more thorough description of the system follows.

Centralized

Centralized wastewater treatment and reclamation facilities are run by three agencies in the Las Vegas Valley, including Clark Country Water Reclamation District (CCWRD), the City of Las Vegas, and the City of Henderson. These centralized wastewater facilities receive sewage from the communities they serve and either discharge the highly treated effluent to Lake Mead or divert it for non-potable reuse at nearby businesses, including golf courses, public parks and power plants. The reclaimed water from these plants is conveyed to the users using a non-potable water main within a dual-distribution system (CCWRD, 2006d; City of Las Vegas, 2006a; City of Henderson, 2006).

Decentralized

Three main decentralized plants exist in the Las Vegas Valley: the Bonanza Mojave Water Resource Center (1999), Durango Hills Water Resource Center (2001) and Desert Breeze Water Resource Center (2003). These decentralized plants receive sewage from residences and businesses in their vicinity and deliver all treated reclaimed water for direct non-potable reuse to nearby customers such as golf courses, public parks and schools. These facilities use small-scale dual-distribution systems to deliver the reclaimed water (City of Las Vegas, 2006a; City of Las Vegas, 2006b; CCWRD, 2006a). The pipes in these systems can be relatively short due to the proximity of the facilities to their end users, as shown in Figure 6.

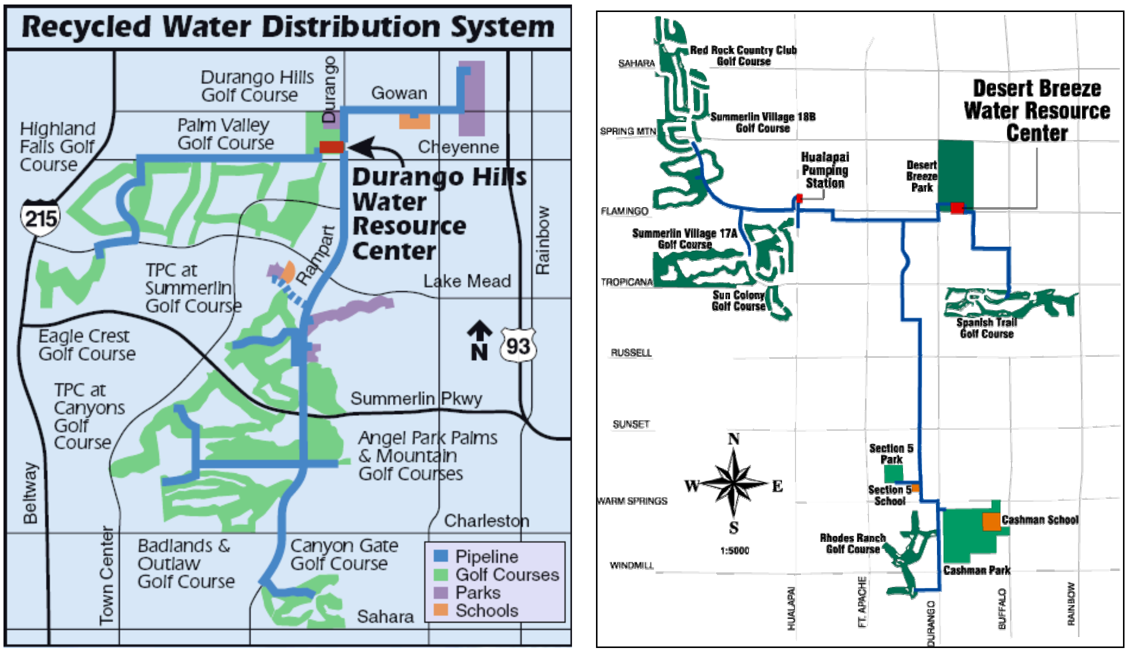


Figure 6: Durango Hills (left) and Desert Breeze (right) Dual Distribution Systems (City of Las Vegas, 2006b), (CCWRD, 2006a)

On-site

At the on-site level, several resorts on the Las Vegas strip are using reclaimed water for their water attractions. One notable example is Treasure Island Cove, a pirate-battle show that is performed in front of the Treasure Island Hotel. Greywater collected from the sinks and showers of 3,000 guest rooms is treated in an on-site reverse-osmosis plant, and is then used to provide water for the attraction, as well as being piped across the street to pour out of the Mirage's simulated volcano (KUED, 2006). As new resorts are being built, the potential of using reclaimed water at the on-site level is being recognized. For example, the new City Center resort is planning on using reclaimed water across the resort (CityCenter, 2006).

A summary of the water reclamation facilities in the Las Vegas Valley is given in

Table 2. Figure 7 shows the location of these facilities.

Table 2: Water reclamation facilities in the Las Vegas Valley

Date of operation	Name of Plant	Location	Capacity	Type	Source of Wastewater	Distribution of Wastewater
1938	City of Henderson Water Reclamation Facility (City of Henderson, 2006, City of Henderson, 2006a)	Henderson	20 MGD (City of Henderson, 2006)	Centralized	Municipal wastewater from Henderson and parts of Vance County	Discharge to Rapid Infiltration Basins, Lake Mead; direct non-potable reuse at golf courses, highway landscapes, construction sites, cemetery.
1954	Clark County Water Reclamation District Main Facility (CCWRD, 2006d)	Las Vegas	96 MGD (planned expansion to 110 MGD)	Centralized	Municipal wastewater from residents and businesses	Discharge to Lake Mead; direct non-potable reuse (power station (since 1958) golf courses (since 1960s), parks (since 2005), fields and landscapes at schools (under discussion) (CWT, 2006) Building a 10-mile, $23.7M pipeline to deliver reclaimed water to more parks, schools and cemeteries; and a future extension of another 7 miles at cost of $17M (Brean, 2004).
1958	Water Pollution Control Facility (City of Las Vegas, 2006a)	Las Vegas	91 MGD (average of 63 MGD in use)	Centralized	Municipal wastewater from residents and businesses in Las Vegas and North Las Vegas	Discharge to Leak Mead for unplanned indirect potable reuse (~90%); direct non-potable reuse at nearby power plant and golf courses (~10%)
1993	Treasure Island Resort (KUED, 2006)	Las Vegas Strip (unincorp-ortated Clark Co.)	100 kGD	On-site	Greywater from sinks and showers of 3,000 hotel rooms	Reverse-osmosis facility provides water for Treasure Island Cove and Mirage Volcano attractions
1999	Bonanza Mojave Water Resource Center (SNWA, 2006a:34, City of Las Vegas, 2006a)	Las Vegas	1 MGD	Decentralized	Wastewater from nearby residents and businesses.	Direct non-potable reuse at nearby park and golf course.
2001	Durango Hills Water Resource Center (City of Las Vegas, 2006b)	Las Vegas	10 MGD	Decentralized	Wastewater from nearby residents and businesses.	Direct non-potable reuse at golf courses, parks and schools. (distributed through 17 miles of pipelines, 2 pumping stations, 4 recharge wells)
2003	Desert Breeze Water Resource Center (CCWRD, 2006a)	Las Vegas	10 MGD (5 MGD in use)	Decentralized	Wastewater from nearby residents and businesses.	Direct non-potable reuse at golf courses, parks and schools.

Figure 7: Location of major centralized and decentralized facilities within the Las Vegas Valley (Google Earth, 2006)

Future Plans

While expanding the reuse of wastewater does not contribute to an increased supply of Colorado River water for Las Vegas, it will be important in the near future when non-Colorado River sources come on-line to augment current resources. These latter sources do not contribute to return flow credits; therefore direct reuse (instead of discharging to Lake Mead) will extend the region's water resources. In addition, recent legislation which requires new golf courses to use reclaimed water for irrigation where available (WRA, 2003) has increased demand for reclaimed water.

To meet increased demand, the water districts are continually looking into ways to increase the use of reclaimed water through building of more reclamation facilities, particularly decentralized facilities (SNWA, 2006a: 33-35):

- City of Henderson: The city of Henderson is currently planning another decentralized water reclamation facility to meet reclaimed water demand in the southern and western parts of Henderson.
- North Las Vegas: Although North Las Vegas currently does not provide reclaimed water, it started to explore the feasibility of building a 20 MGD reclamation facility in 2004.

- Clark County: Clark County has embarked on an "In-Valley Water Reclamation Facilities Master Plan" to examine how to meet the reclaimed water demand in its service area.
- Valley-wide efforts: An "Area Wide Reuse Study" was completed in 2000 to evaluate suitable locations for future wastewater reclamation plants in the Las Vegas Valley.

In addition to building new decentralized plants, water districts are also looking into increasing the level of direct reuse from centralized plants through the building of new pipelines and other infrastructure to customers within their close vicinity (Brean, 2004).

2.9 Conclusion

Las Vegas is clearly in a dire situation with regards to its water resources. Its water supply is constrained by historical contracts and the surrounding desert environment, while its demand for water is growing quickly. As it seeks to gain access to new sources of water elsewhere in the state, Las Vegas is making the most of its potable water supply by offsetting demand through water reclamation and reuse. By pursuing and encouraging a range of water reclamation technologies at a number of scales, Las Vegas is working to match different approaches to water reclamation to users who can use them most appropriately. The use of centralized reclamation facilities for golf courses and municipal parks, decentralized facilities for golf courses across the city, and on-site systems for resorts indicates that Las Vegas is pursuing a flexible set of solutions to address its water supply problem.

3
Issue Framing

3.1 Issue Framing through Goals, Castings, and Boundaries

Water reclamation in Las Vegas — as with any application of technology in a political context — is a complex issue influenced by various factors and interests that are all a part of a larger system of water resource management for the City of Las Vegas. The future development of water reclamation as a source of water supply for the city will not happen accidentally or serendipitously: it will result from a conscious application of reclamation technology as a solution to the growing challenge of water management in the Las Vegas Valley.

In this way, water reclamation is a mindful choice exercised in order to address the perceived challenges of water resource management. The act of selecting water reclamation as a strategy introduces implicit assumptions of the nature of the water resource challenge, the alternatives available to overcome it, and the overarching goals of water management. However, these assumptions must be carefully balanced against the interests and factors involved in an issue; as social and political influences are inherently active within framing policy strategies around an issue such as water reclamation, they must be explicitly taken into account in the process of framing the goals, casting, and boundaries of an issue (Patton and Sawciki, 1993: 168-169; Weigel, 2006).

Table 3 was developed to provide an illustrative tool of how casting the issue of water management can lead to different types of goals, and the placement of boundaries onto an issue which limit the breadth of factors considered in developing policies.

Table 3: Framing water reclamation according to different castings, goals, and boundaries

CASTING	**GOALS**	**BOUNDARIES**
Overarching Views		
Sustainability	Ensure ongoing availability of water for future generations	Temporal / time horizon Monthly Annual Decadal Millennial
Economic	Develop a cost-effective, profitable water system Provide sufficient water to enable economic growth	Financial bottom line Monetary value Fiscal attractiveness Availability of resources
Approaches		
Supply-side management	Augment water supply	Physical infrastructure Centralized Decentralized On-site
Demand-side management	Enable equitable access to water Offset potable water use Maximize water conservation	
Issues		
Environmental	Provide water while maximizing environmental benefits and minimizing environmental damage	Geophysical boundaries Las Vegas Wash Colorado River Aquifers Surface waters
Health	Ensure a safe supply of water for human consumption	Management systems Policies and regulations Technical feasibility Process control System reliability Monitoring
Control / regulation	Secure water system reliability and operation	
Perception	Inspire feelings of confidence in users of system	Societal acceptance and involvement Multi-stakeholder representation Level of trust
Security	Protect water system from disruption or attack	Planning and organizational bounds

3.2 Types of Policy Issue Castings within Water Reclamation Management

The different castings proposed in Table 3 draw from the committee's expertise in water reclamation issues, as well as communication with several water resource experts (Parker, 2006; Pharino, 2006; Venema, 2006). The first two castings — sustainability and economic — represent overarching views of reclamation systems. Sustainability involves a long-term view of a water resource system, while an economic casting focuses on both the revenue of the system as well as the local economic growth enabled by the water system.

Supply- and demand-side management strategies offer two different approaches to water management. Supply-side management focuses on the development of new water sources, while demand-side management considers how and where water is used by consumers, and favors measures such as conservation and increased efficiency. For example, Gleick (1995) uses demand-side driven "soft paths" concepts to propose a system to meet the demands of California without the need for new infrastructure or technological advances.

Finally, environmental, health, perception, regulation, and security castings are specific issues that influence water resource management technologies and policies. Each of these castings affect water reclamation in important ways, and will be individually explored as specific interactions between technology and policy within the Las Vegas context. These issues tend to resound with specific groups of stakeholders, and are therefore important in understanding the motivations and interests of different groups who play a role in water management.

3.3 Developing an Integrated Management Framework

In Las Vegas, there is a lack of evidence of a deliberate attempt to frame the role of water reclamation within a water resource management framework. At the state level, there is evidence that Nevada failed to communicate a cohesive vision through its water policy efforts, as evidenced by the defeat of a recent water conservation bill[6] due to opposition from mining, labor and urban growth groups (Hennessey, 2005). On the other hand, while it seems that decision-makers in Las Vegas have neglected a formal issue framing process, it appears that agencies implicitly acknowledge the importance of pursuing numerous goals across many of the castings presented in Table 3. For example, the SNWA's water resource plan contains both supply- and demand-side management strategies as well as a chapter on environmental planning (SNWA, 2006a). An example of a demand-side management strategy includes a set of service rules enforced by the LVVWD around limiting wasteful uses of water and outdoor watering restrictions (LVVWD, 2006).

This suggests that — forgoing a formalized issue framing process — the SNWA and other agencies are aware of the broad range of water management alternatives available, and are willing to challenge the issue of water management with a variety of different approaches. Regardless, whether it is done implicitly or explicitly, issue framing will inherently influence the articulation of water reclamation policy goals. It is important for decision-makers to recognize the role of issue framing, and ideally articulate a purposeful, overarching vision for water resource management. Such a vision would reveal the underlying casting and goals of water reclamation, specifying its role clearly within an integrated water management framework.

[6] This conservation bill, bill AB434, would have "provided a process and funding to clarify the status of existing water rights and require public hearings on any interbasin water transfers." Ensuring that all decisions made by the State Engineer are in the public's best interests, the bill would have also required the state Environmental Commission to include an expert in conservation.

4
Stakeholder Analysis and Mapping

The use of reclaimed water brings about widespread impact, and its success hinges on public and stakeholder acceptance. Thus, it is critical to identify these stakeholders, consider their motivations, core values and beliefs, and determine how they are aligned on the issue (Weigel, 2006). It is also important to understand their power, or degree of influence, as well as their interest and position on water reclamation.

4.1 Types of Stakeholders

The key stakeholders with water reclamation interests in Las Vegas can be classified into three primary categories: (i) government; (ii) the public; and (iii) industry.

Government

Government agencies include those involved in water resource planning or directly responsible for implementing and operating wastewater reclamation facilities in the Las Vegas region, as well as agencies at the state and federal level. At the state level, the Nevada Division of Water Resources (NDWR), Nevada Division of Environmental Protection (NDEP), and neighboring state governments have an interest in how Las Vegas manages its reclaimed water discharge into the Colorado River. Federal agencies such as the EPA and the NRC express interest in how water reclamation solutions in Las Vegas can better inform national policy.

Public

In terms of public actors, there are environmental groups as well as local community members who voice either support or opposition for water reclamation. To represent the interests of citizens in Las Vegas' water reclamation strategy, citizen advisory committees have been established and these constitute important public multi-stakeholder groups.

Industry

Industrial stakeholders primarily consist of commercial consumers of reclaimed water. These are mainly local golf courses, which are required to use reclaimed water for irrigation where it is available (SNWA, 2006a: 34). Those using large amounts of water for landscape irrigation, such as resort facilities, schools, and parks, are also stakeholders with non-potable reclaimed water interests. Additionally, local and national contractors and suppliers in the water reclamation industry are affected by water reclamation projects in Southern Nevada.

Table 4 provides an analysis of the various stakeholder groups in Las Vegas at the state and national level, as well as their core beliefs, motivation and degree of influence in wastewater reclamation.

Table 4: Stakeholder analysis of water reclamation issue

	Key Stakeholders	Function	Core Values / Beliefs (Mission)	Dominant Motivations[7]	Power / Influence
Government	Bureau of Reclamation (Bureau of Reclamation, 2006)	Agency responsible for water management throughout four inter-state regions in the western United States.	"Manage, develop, and protect water…in an environmentally and economically sound manner" (Bureau of Reclamation, 2006a)	*Control / regulation, economic, environment:* Managing water resources to support western U.S. growth, economy.	Large, diffuse power through management of Colorado River resources and in-state water resources. (SNWA, 2006a)
Government	Nevada Division of Water Resources (NDWR) (NDWR, 2006)	Regulatory agency which oversees the distribution and use of Nevada's water resources.	"Conserve, protect, manage and enhance the State's water resources …through the appropriation and reallocation of the public waters"	*Control / regulation, environment:* Regulating the sustainable use and distribution of water resources.	Large, diffuse power as state regulator in wastewater reclamation.
Government	Nevada Division of Environmental Protection (NDEP) (NDEP, 2006a)	Regulatory agency which oversees the protection of Nevada's natural resources, including water resources.	"Preserve and enhance the environment of the state in order to protect public health, sustain healthy ecosystems and contribute to a vibrant economy" (NDEP, 2006a)	*Control / regulation, environment, economic, health:* Managing water resources in balance between environment and economy.	Large, diffuse power as state regulator in wastewater reclamation.
Government	Las Vegas Wash Coordination Committee (LVWCC) (LVWCC, 2006)	Coalition of stakeholders related to the Las Vegas Wash to address all issues related to it.	"Evaluate all facts, issues, and concerns regarding the Las Vegas Wash in order to develop and implement a practical, comprehensive approach for managing the Wash in a timely manner." (LVWCC, 2006a)	*Environment:* Stopping the adverse environmental impacts in the Las Vegas Wash.	Low, focused influence through studies of impact of wastewater effluent flow in Las Vegas Wash.
Government	Southern Nevada Water Authority (SNWA) (SNWA, 2006a)	Key agency in developing and managing the resources and infrastructure necessary to meet South Nevada's water needs.	"Manage the region's water resources and develop solutions that will ensure adequate future water supplies for the Las Vegas Valley" (SNWA, 2006a)	*Supply-side management, sustainability*: Securing a sufficient water supply for Southern Nevada.	Large, direct influence in strategizing wastewater reclamation initiatives.

[7] For the different categories used to sort the dominant motivations of each stakeholder, refer to Section 3 on Issue Framing.

Key Stakeholders		Function	Core Values / Beliefs (Mission)	Dominant Motivations[7]	Power / Influence
	Las Vegas Valley Water District (LVVWD) (LVVWD, 2006b).	Provides water to the Las Vegas Valley; enforces the district price rates for potable and reclaimed water usage.	"Partner to provide reliable, quality water, ensuring the sustainability of our desert community and serving our customers responsibly" (LVWCC, 2006b)	*Control / regulation, supply-side management, sustainability:* Delivering a sufficient water supply for the Las Vegas Valley.	Large, direct influence through pricing and distribution of reclaimed water.
	City of Las Vegas Public Works Department (City of Las Vegas, 2006)	Operates wastewater treatment and reclamation facilities in cities of Las Vegas and North Las Vegas.	"Meet and exceed state and federal requirements for the safe return of water to the Las Vegas Wash and Lake Mead" (City of Las Vegas, 2006)	*Control / regulation, economic, health, environment:* Cost-effective processing of wastewater to a safe standard.	Large, direct influence through planning, implementing and operating wastewater reclamation plants
Government	Clark County Water Reclamation District (CCWRD, 2006)	Operates the largest wastewater treatment and reclamation facilities in Southern Nevada.	"Manage reclaimed water as a resource" (CCWRD, 2006b); "working hard ..to protect public health, preserve our environment" (CCWRD, 2006c)	*Control / regulation, economic, health, environment:* Cost-effective processing of wastewater to a safe standard.	Large, direct influence through planning, implementing and operating wastewater reclamation plants.
	City of Henderson Utility Services (City of Henderson, 2006)	Operates water and wastewater treatment and reclamation facilities in City of Henderson.	"Provide quality water, wastewater and reclaimed water service to the public…at equitable rates.. within established ordinances and regulations" (City of Henderson, 2006)	*Control / regulation, economic, health, environment:* Cost-effective processing of wastewater to a safe standard.	Large, direct influence through planning, implementing and operating wastewater reclamation plants.
	Clean Water Coalition (CWC) (CWC, 2006a)	Coalition of 3 agencies responsible for wastewater treatment in Las Vegas Valley "to assess the future of wastewater treatment and discharge" in the Las Vegas Valley.	"Identify and implement environmentally and financially sound long-term solutions for the treatment, discharge and reuse of…wastewater" (CWC, 2006a)	*Control / regulation, sustainability, economic:* Halting the current practice of unplanned indirect potable reuse of water in Las Vegas.	Large, direct influence in wastewater discharge and reuse.
	EPA	"Leads the nation's environmental science, research, education and assessment efforts" (EPA, 2006e)	"Protect human health and the environment" (EPA, 2006e)	*Control / regulation, environment:* Outlining national guidelines for water reclamation.	Large, diffuse power through regulating reclaimed water quality, and also in public education of wastewater reuse.

	Key Stakeholders	Function	Core Values / Beliefs (Mission)	Dominant Motivations[7]	Power / Influence
	NRC (National Academies, 2006)	Further scientific, technological and health knowledge and advise the federal government in these matters.	"Provide science, technology and health policy advice" (National Academies, 2006)	*Perception*: Advance expert views, perception of water issues.	Smaller, diffuse influence through policy studies in wastewater reclamation.
	Other State Governments (e.g. California, Arizona)	Lead and manage the interests of each government's respective state.	Not applicable.	*Control / regulation, security, sustainability*: Provide sufficient water for each state's sovereign needs.	Low, diffuse influence on wastewater reclamation.
General Public	CWC Citizens Advisory Committee (CWC, 2006a)	Represents the interests of community, industrial, academic, and social interest group stakeholders in making recommendations on the work of the CWC.	Help CWC to "identify and implement environmentally and financially sound long-term solutions for the treatment, discharge and reuse of our community's wastewater…" (CWC, 2006a)	*Perception:* Each member is motivated to represent the interests of his or her own group, and advance its agenda with respect to water reuse.	Direct influence in decisions to implement wastewater reclamation projects.
General Public	Environmental groups	Provide grassroots-level support for wastewater use. Assess local environmental issues and disseminate knowledge to public.	Various	*Environment, health*: Advance environmental issues and concerns.	No direct power, but influence decisions through lobbying or participation in citizen advisory committees.
General Public	Community (skeptics and proponents)	Primary consumers of water provided by City of Las Vegas.	Not applicable	*Perception, security, health, environment*: Impact of water reclamation on individual interests.	No direct power, but influence decisions through lobbying or participation in citizen advisory committees.
General Public	Academic experts	Assess local environmental issues and disseminate knowledge to public and regulatory agencies.	Not applicable	*Perception*: Advance individual opinion, perception of water issues.	Direct influence through advisory, expert role in wastewater reclamation.
Industry	Wastewater industry	Provide planning, installation, and operational support for wastewater infrastructure	Various	*Economic, security:* Profit from the promotion of wastewater technologies.	No direct power, but influence decisions through lobbying or participation in citizen advisory committees.
Industry	Industrial consumers (e.g. golf courses, schools, parks, resorts) (skeptics and proponents)	Provide various community services to the general public.	Various	*Economic, security*: Maintain or increase level of service, or profit.	No direct power, but influence decisions through lobbying or participation in citizen advisory committees.

4.2 Stakeholders Maps

Interest and Alignment Map

Figure 8 shows a stakeholder map developed for the Las Vegas case study based on stakeholder interest and alignment on wastewater reclamation issues, drawn from the information presented in Table 4. A number of government, public, and industry groups are generally aligned with the goal of water reclamation in Las Vegas, but differ in their level of perceived interest in this issue. A few actors, such as NRC and EPA, have broad interests in how water reclamation unfolds in Las Vegas, but are relatively neutral with regards to the issue. In addition to these actors, there exist groups such as industry and community skeptics are generally against wastewater reuse for reasons that will be explored later in the Section 5.1 (Public Perception) of this report.

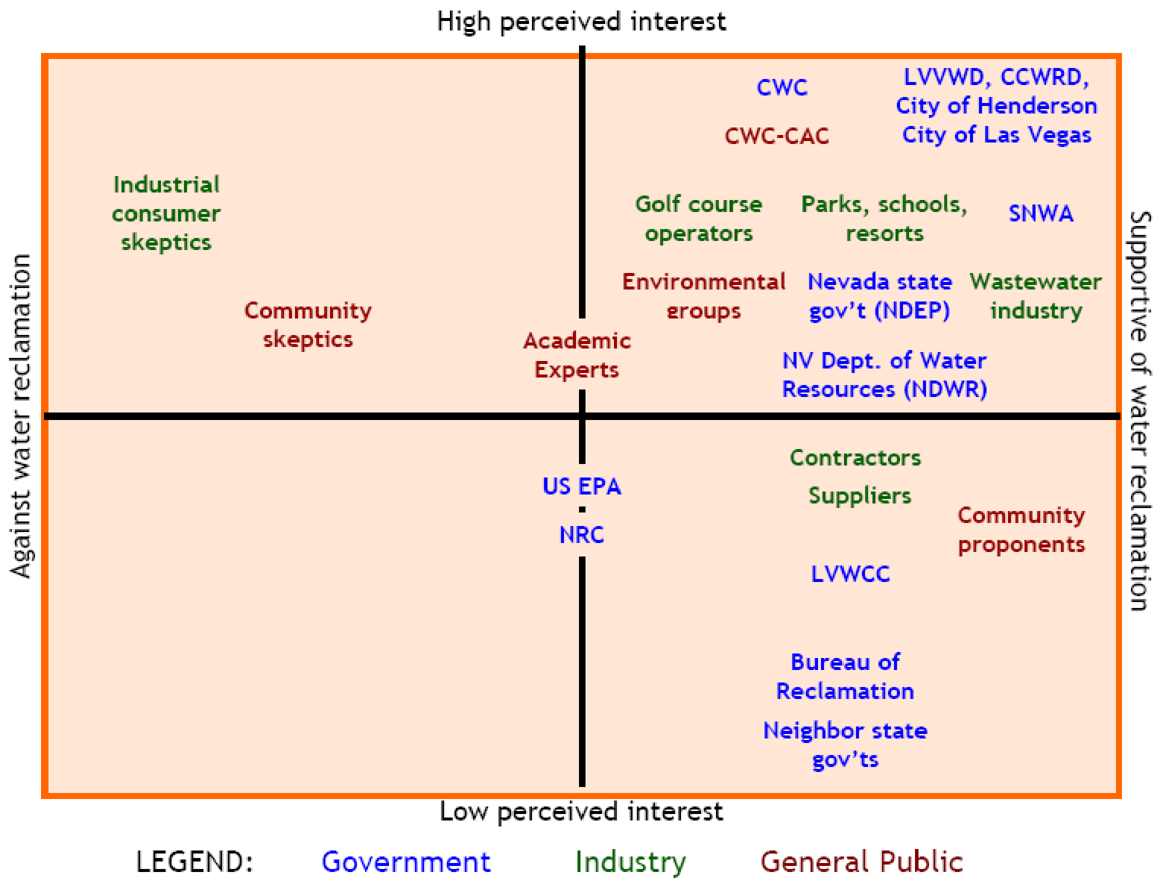


Figure 8: Map of stakeholders' perceived interest in reclamation versus level of alignment with its goals

In order to successfully implement reclamation strategies, it is critical to address the concerns of skeptic groups who have a direct interest in reclamation projects but are opposed to their implementation. In Las Vegas, this has been achieved to some success through the creation of a multi-stakeholder group known as the Clean Water Coalition's Citizens Advisory Council (CWC-CAC). The CAC was formed by the Clean Water Coalition (CWC), a group of three water reclamation facility operators[8] in Southern Nevada. The goal of the CAC is to support the CWC in developing solutions to the treatment and reuse of the community's wastewater. The CWC-CAC comprised 30 members who represent a broad range of stakeholder interests. The key outcome of the CWC-CAC is shown in Figure 8. By empowering a group of public stakeholders, the CWC translated a broad collection of industrial, environmental, and community members into a focused body with direct interests in water reclamation and highly aligned goals.

Interest and Influence Map

Figure 9 is another map showing how the stakeholders are arrayed based on degree of interest and degree of influence in water reclamation in Las Vegas. In particular, stakeholders with (i) high interest and high influence form the most critical stakeholder group and should be fully engaged in the decision-making process; (ii) low interest and low influence are of lower priority but should be monitored; (iii) high interest but low influence need to be more directly involved or empowered, or at the very least kept adequately informed; (iv) low interest but high influence should be consulted and their views or advice incorporated in the decision-making process (WHO, 2006; Urban, 2001).

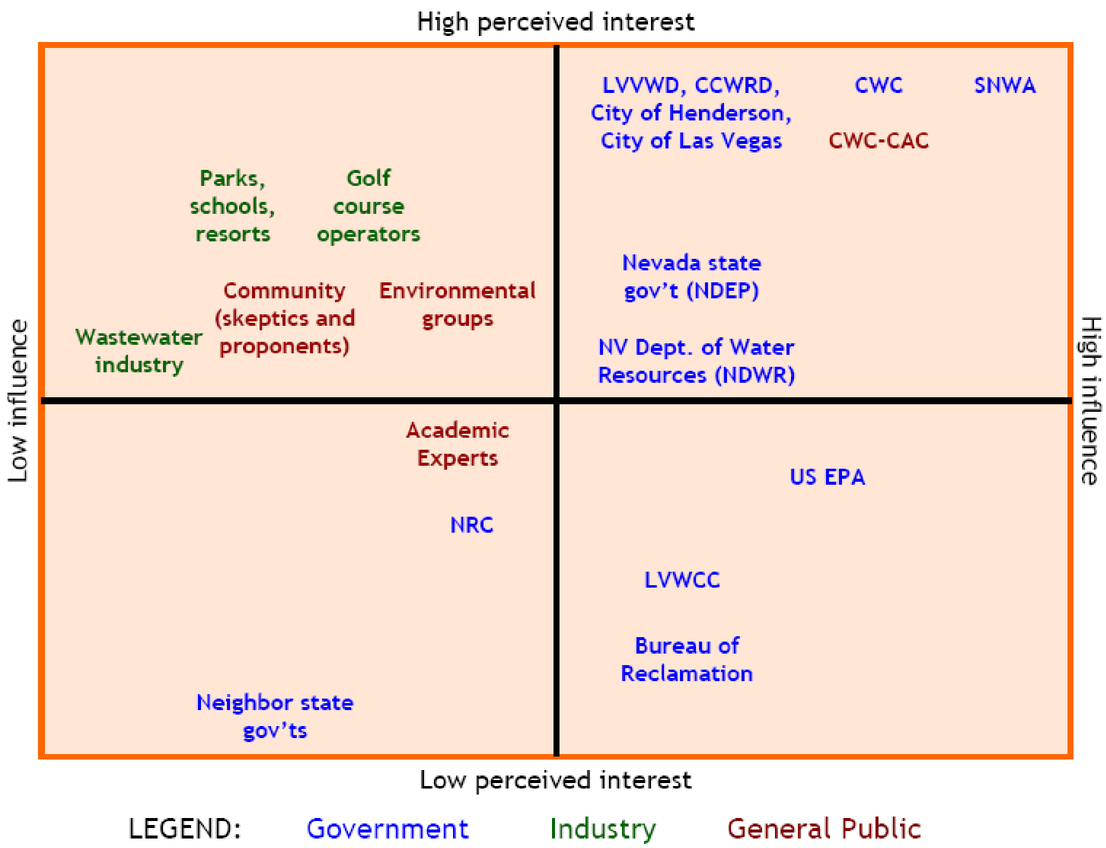


Figure 9: Map of stakeholders' perceived interest in reclamation versus their level of influence

[8] These are the City of Las Vegas, City of Henderson and the Clark County Water Reclamation District.

4.3 Conclusions

In this section, the committee identified the key stakeholders involved in wastewater reclamation in Las Vegas. Their specific functions and core beliefs steer their motivations in this issue. The governmental agencies at the various levels (federal to local) are mainly motivated by the sustainability of health, environmental, and economic priorities in water resource provision and management. Their degree of influence in wastewater reclamation policy is varied and depends on the proximity of their jurisdiction in this issue. Public stakeholders, on the other hand, are primarily concerned with health and environmental impacts of wastewater reuse. Perception is an important factor influencing their support for this issue. The industrial contractors and customers are mainly motivated by economic gains in wastewater reuse. Both the public and industrial stakeholders have direct interests in wastewater reclamation but relatively low influence in the matter. These are important stakeholders to bring on-line in the decision-making process to increase support and acceptance for the implementation of wastewater reclamation projects. The formation of the CWC-CAC is an example of the implementation of this stakeholder empowerment strategy.

The stakeholder analysis and mapping performed in this section lays the foundation for developing strategies to achieve support as well as reducing obstacles to the successful implementation of wastewater reclamation projects in Las Vegas.

5
Policy Issues

This chapter explores a list of key issues surrounding wastewater reuse, particularly how they could constrain or enable the application of wastewater reclamation technologies and vice versa; as well as the successes and challenges Las Vegas faces in overcoming potential barriers these issues pose in wastewater reuse.

5.1 Public Perception

In wastewater reclamation projects, the public are critical stakeholders, and their perception has a strong role in either constraining or enabling the success of the projects. Public perception considerations can sometimes supersede environmental or economic ones, to the extent that decisions in such projects are often based on perception of risk rather than an actual assessment of potential hazards (Friedler, 2006; Robinson, 2005). For instance, a number of large-scale wastewater reclamation projects both in the U.S. and around the world have been constructed, but were unable to start operation as a result of public resistance[9] (Po, 2004).

Factors Affecting Perception

Public aversion to reclaimed water generally increases alongside the degree of contact with the reclaimed water (Friedler, 2005). Perceptions are shaped by factors such as the “yuck factor” associated with idea of ingesting water made from dirty wastewater effluent containing bodily fluids, excrement, and pollutants. Although people may recognize the importance of reclamation, they are reluctant to use reclaimed water themselves, a symptom dubbed the “Not-In-My-Backyard” (NIMBY) syndrome (Po, 2004). These concerns can be mitigated by a level of trust in the treatment technology, or in areas with acute water shortages where conservation efforts are already a necessity (Po, 2004). In this way, policies that promote awareness of reclamation can enable the application of the technology.

In fact, education of public stakeholders appears to have a greater influence on acceptance than whether the proposed project is a centralized, decentralized or on-site system. While there does not seem to be a public consensus on the type of system preferred, the level of acceptance appears to be heavily influenced by the level of information conveyed to the public (Po, 2004). Negative perceptions of wastewater reclamation schemes often stem from a lack of accurate information about such schemes, coupled with the natural human reaction to find the reuse of previously dirty or toxic water unpalatable. Where these perceptions exist, policies are required to enable reclamation technology. Some strategies include: (i) the formation of public stakeholder groups who are included in decision-making at an early stage in the process; (ii)

[9] A case in point is the failure of the Department of Water and Power in Los Angeles, California, in 2000 to implement a $50 million distribution system for reclaimed water after it was built. Insufficient education of the public about the wastewater reclamation project, coupled with fear-inducing “toilet-to-tap” newspaper headlines were sufficient to create panic and strong public opposition, causing the project to be axed. (WRRIC, 2006)

providing public education programs around water reclamation strategies; and (iii) enabling transparent public access to information on proposed reclamation projects (Po, 2004).

Perception Issues in Las Vegas

Water reclamation issues in Las Vegas are no exception to the important role of public perception. The city's location in an arid desert environment has generally instilled in its residents a heightened sense of the scarcity of water and the importance of water conservation and reclamation (Archuleta, 2004; CCWRD, 2006). In addition, the extremely high standard of wastewater treatment in Las Vegas has likely contributed to a good level of trust in the community that the authorities have the technologies and competence to provide safe and high quality reclaimed water.

On the other hand, Las Vegas' current practice of unplanned indirect potable reuse has the potential to create adverse public perception issues. Community skeptics of reclamation technologies are mainly concerned about the perceived health risks of wastewater reuse (CWC, 2006). These groups have a relatively diffuse ability to influence decision-makers, but if they concentrate their power through channels of grassroots advocacy or lobbying against reclamation projects, they can pose a significant barrier to the implementation of these technologies. Therefore, despite Las Vegas' position in a water-constrained area with a public body that is aware of water issues and the importance of reclamation, perception issues can still play a critical role in the success of reclamation projects.

Stakeholder Engagement

Interestingly, the SNWA and CWC's have approached the issue of public perception through inclusive policies that have likely helped to enable the application of water reclamation technology. In forming the CWC-CAC and other multi-stakeholder groups, these agencies have created public groups of informed, empowered actors who have chosen to align themselves with the goal of water reclamation in Las Vegas. Specifically, they have made recommendations to expand wastewater reuse[10]. Empowering these groups of diverse interests appears to have helped Southern Nevada authorities deal with skepticism in the community, and ultimately advance their favored strategy of water reclamation in Las Vegas. For example, the decision to build the Desert Breeze Water Resource Center (decentralized water reclamation plant) has in part stemmed from the recommendation of a citizens advisory committee, as well as other public outreach and consultation efforts like surveys, public meetings and dialogues with commercial customers (CCWRD, 2006). In this way, the government has succeeded in enabling the technology by delegating decision-making responsibility to the public and including them in the process of water resource management from an early stage.

[10] For example, the Integrated Resources Plan Advisory Committee, a citizens committee created by SNWA "recommended maximizing the reuse of wastewater where practical"; and the Water Quality Citizens Advisory Committee "recommended greater on-site reuse to reduce flows from treatment plants into the Wash" (LVWCC, 1999: Ch 8)

Public Education

In addition to direct stakeholder involvement, extensive public education and information dissemination when implementing wastewater reclamation projects is important to increase public buy-in. Provision of information has been shown to alleviate negative perceptions about water reclamation, particularly its perceived health risks (Po, 2004). Media management is an important part of this communication effort as it is the main channel through which the public receive information on the project (Robinson, 2005).

In Las Vegas' implementation of the Durango Hills Water Resource Center, a Community Relations and Public Involvement Program was developed. Under this program, public education materials such as short documentaries, brochures, fact sheets and project newsletters were disseminated. Public information meeting, public enquiry hotlines and field trips to other wastewater reclamation projects were organized. The program administrators also worked with the media to provide informative news releases of the project (CWSD, 2006).

Perception of Key Commercial Customers

Businesses such as golf courses and resorts, and to a lesser extent, schools and parks, are the main customers of non-potable reclaimed water in Las Vegas. Their role has been recognized through representation in multi-stakeholder groups created by the SNWA and CWC.

Golf course users are a particularly important stakeholder group, as golf course irrigation can consume up to a million gallons of water per day (Grinnell, 2006). Since 2003, the LVWWD has restricted golf course operators to a "water budget" which constrains the volume of water that can be used for irrigation, and has required that reclaimed water be used wherever it is available (Grinnell, 2006; WRA, 2003). This has placed superintendents in a tough position, and they are generally frustrated by the high costs of water and the constraints placed on its use (Grinnell, 2006).

At the same time, reclaimed water is provided to approximately 30 golf courses in the Southern Nevada region. This resource offers a slightly cheaper supply of water (refer to Section 5.4), and it has been found that people generally expect to pay less for recycled water due to its lower quality (Po, 2004). However, the high salinity of the reclaimed water is difficult to manage and requires special seeding practices which may negate some of its cost benefits (Grinnell, 2006). The most important factor in acceptance of reclaimed water by superintendents appears to be their personal level of knowledge and experience with it as a resource. This learning process is further enabled through direct engagement by water agencies such as the LVVWD. For instance, the LVVWD attends the meetings of professional organizations such as the Southern Nevada Golf Course Superintendents Association (Grinnell, 2006).

Engagement has allowed officials to implement regulations and reclaimed water policies in a way that has prevented large disruptions to golf course operations, and has lead to a greater alignment of operators with reclaimed water reuse. A 2004 national survey of golf courses across the U.S. found that 63% of superintendents were positive about using reclaimed water and that 28% were neutral while 4% felt negatively. It is believed that superintendents in Southern Nevada roughly follow this trend (Grinnell, 2004).

Resorts and hotels are smaller, point-source users of water, and do not receive reclaimed water from centralized or decentralized plants. Even so, several resorts have begun using on-site reclamation methods to offset their potable water demand. The primary driver for this has been the recognition of a "civic responsibility" to be "good partners…in the valley" and the belief that they "are going the extra mile" (KUED, 2006). The City of Las Vegas is also planning to provide incentives to promote the installation of on-site reclamation facilities at hotels and resorts (City of Las Vegas, 2005). Finally, administrators of public parks and various schools in the region also expressed support for the use of reclaimed water for the irrigation of their landscapes and turfs (Brean, 2004).

Conclusion

The early involvement and empowerment of public stakeholders through participation in the decision-making process, coupled with a comprehensive and transparent public education and outreach strategy, are important ingredients to increase public acceptance of water reclamation projects. An incentive-based framework can serve to promote wastewater reuse, especially when such use is mandated by regulations.

In general, agencies such as the SNWA and CWC seem aware of the importance of public perception and have employed appropriate measures to address this critical issue. Through the creation of multi-stakeholder groups, implementation of comprehensive public communication programs and the use of complementary policy measures, Las Vegas appears successful in enabling reclamation technologies by overcoming potential perception barriers.

5.2 Human Health

The protection of human health and safety is of principal concern to water reclamation strategies. Inappropriate reuse of reclaimed water can pose significantly harmful health impacts to the public (NRC, 1994: 9). The potential health risks of using reclaimed water depend on:

- i) the level of public exposure from the end-use of reclaimed water;
- ii) the level of water quality that can be guaranteed by the reclamation system;
- iii) the selection of the reclamation technology type, whether centralized, decentralized, or on-site; and
- iv) the perception of the public towards health risks posed by reclamation strategies.

End-Use of Reclaimed Water

First, in terms of end-use, a critical distinction must be made between potable and non-potable water end-uses. Reclaimed water used for non-potable applications involves a relatively low exposure risk, as the water is not directly consumed by the public, and the level physical contact with the water is low. Even so, non-potable end uses may still present health concerns given public contact through recreation, irrigation, and aesthetic applications. Using reclaimed water for potable end uses poses an even higher exposure risk, as the public directly consumes potable water resources on a daily basis (Okun, 2000).

Currently, the City of Las Vegas practices unplanned, indirect potable reuse of reclaimed water by withdrawing its drinking water from Lake Mead, then discharging its treated effluent water back into the lake. The elevated risk of exposure through this potable reuse of reclaimed water poses a significant health risk to the public. Additionally, the volume of reclaimed water discharged into Lake Mead is increasing during a time of drought, where the lake is less able to dilute and process any urban contaminants present in the treated effluent. In order to guard against these elevated risks, a comprehensive control strategy is critical in ensuring that the quality of reclaimed water is sufficient to protect public health.

Water Quality

A water quality control strategy should include the following elements: (i) preliminary risk assessment, followed by (ii) health and safety testing, (iii) water quality monitoring, and (iv) system reliability evaluation (NRC, 1998). However, current technologies in these areas still present key uncertainties which limit the recommendation of water reclamation for potable use. Table 5 summarizes the uncertainties that persist among the different elements of water reclamation systems.

Table 5: Aspects of uncertainty in system elements required for water reclamation processes (adapted from NRC, 1998; Toze, 2006; Asano, 2004)

SYSTEM ELEMENT	UNCERTAINTY	SAFEGUARDS
Risk assessment	Estimates of hypothetical risk involved	Define acceptable concentration levels Restrict reclaimed water to non-potable, indirect potable end uses
Health and safety testing	Health effects of natural organic compounds, DBPs Long term effects of microbial, chemical contaminants	Regulation of concentration levels
Water quality monitoring	Detection of pathogens	Multiple treatment barriers
System reliability evaluation	Reliability of treatment methods in pathogen removal Reliability of environmental process and organisms	Overestimation of actual risk from pathogens Restrict end use of reclaimed water

In general, uncertainties such as risk assessment, the long term health effects of certain compounds, detection of pathogens, and the level of system reliability are mitigated through safeguards. These safeguards are typically measures which attempt to overestimate the level of risk, or build factors of safety into the design of a system. For example, safeguards include: regulating the appropriate level of contaminant concentration levels in reclaimed water, multiple and duplicating steps in the treatment process, the overestimation of risks, and with the underestimation of system performance and reliability. It should be noted that while systems can treat reclaimed water to a very high level of purity, these advanced technologies are usually associated with high costs (e.g. reverse osmosis) which may limit their use (Toze, 2006; Pharino, 2006).

It appears that Las Vegas has primarily used advanced treatment safeguards to control the public health risks presented by the city's practice of indirect potable reuse. The three reclamation plants which discharge reclaimed water into Lake Mead are the most advanced in the United States (CWC, 2006a). In addition to these robust treatment facilities, studies are underway to determine other options for reducing public exposure to unplanned indirect potable use of reclaimed water. For example, the CWC is currently assessing alternative discharge points for reclaimed water downstream in the Colorado River, further away from the pipelines which draw water to the water treatment facilities for potable use (CWC, 2005). In addition, long term monitoring is being conducted on effluent discharged into Lake Mead, and there are attempts to rehabilitate wetlands along the watercourse to better cleanse the flow of urban chemicals and hazardous organisms (LVWCC, 1999).

Centralized, Decentralized, and On-site Approaches

A third factor that impacts health issues is the selection of centralized, decentralized or on-site technology approaches to water reclamation. The choice of these technologies may directly constrain policies based on their effect on the level of health risk posed to the public. Hence, the features and applicability of these technology approaches can be important factors in influencing an implementing agency's policy decisions relating to wastewater reuse.

Generally, the health risks of larger scale, centralized water reclamation facilities are the most pronounced of the three technology approaches. These risks result largely from acceptance of sewage and wastewater from a large number of users, high rate of throughput, and contamination risks involved through mixing of effluent with natural potable water sources. Decentralized systems pose less public health risk than centralized systems. They generally process the same type of wastewater as centralized systems, but at a smaller input volume and throughput demand. Also, decentralized systems have less potential for contamination of potable water sources, particularly if the reclaimed water is directly distributed to end-users. On-site systems present the lowest health risk among the three approaches due to their small, localized scale, "cleaner" grey or storm water inputs, as well as the direct, non-potable use of their outputs.

Public Perception of Health Risks

Fourth, the perceived risk of water reclamation to human health is another important consideration because this strongly influences stakeholder acceptance to wastewater reclamation projects. Hence, it is imperative for implementing agencies to not only ensure that the appropriate regulatory requirements are met, they must also demonstrate to public stakeholders that these regulations are in place and that they are in compliance with them (NRC, 1998: 13). For example, safety assurance and transparency could be developed through enabling public access to continuous water quality monitoring data over the internet. Providing this technological service could help increase the level of public acceptance and trust in a water reclamation project. Las Vegas has yet to implement such specific stakeholder engagement technologies, but they have succeeded in building public confidence in water reclamation through multi-stakeholder groups and effective policy mandates for industrial users, as discussed in the Public Perception section of this report.

Conclusion

The interconnected nature of health issues creates a complex framework for water reclamation strategies, one that requires a robust system of management and safeguards in order to mitigate risk and uncertainty to an appropriate level. Las Vegas has dealt with the serious health risks posed by its unplanned indirect potable reuse of reclaimed water through increasing its level of water treatment and developing monitoring programs. However, there is no evidence that risk assessments and system reliability adequately account for the serious nature of unplanned indirect potable reuse. While the city continues to explore alternatives that will mitigate these risks, it has succeeded in engaging public stakeholders, which will likely positively impact local stakeholders' perceptions of these ongoing efforts.

5.3 Environment

Water reclamation poses both benefits and risks to the environment. On one hand, the use of reclaimed water can offset disruptive diversions from natural water sources, as well as reduce water pollution by eliminating the need to discharge wastewater into natural sources (EPA, 2006a). At the same time, two aspects of water reclamation pose significant risks to the environment: (i) the discharge of reclaimed water into natural waterways, and (ii) disposal of residual solid waste (i.e. biosolids) generated from reclamation processes. These risks are complicated by their interface with human health and public perception issues (NRC, 2000: 88-89).

Risks associated with discharge of reclaimed water

In Las Vegas, most of the water reclaimed from the wastewater treatment plants is discharged to the Las Vegas Wash, a 12 mile long "urban river" comprised of urban runoff, groundwater and storm water flows from the city. The Wash environment is instrumental in filtering the reclaimed water discharged from the three treatment plants, but is also sensitive to environmental issues that may compromise its ability to safely dilute and deliver reclaimed water to Lake Mead.

In addition to the discharge of reclaimed water, the growth of Las Vegas has caused three important environmental impacts within the Wash: (i) dramatic erosion from sudden increases in storm water run off and flood events; (ii) water quality concerns from urban chemicals, (iii) the decline in natural wetlands and habitat (LWCCC, 1999: 2). Additionally, the Las Vegas Valley's current hydrological situation is complicated by severe drought conditions, as shown in Figure 10. Not only has the drought reduced the availability of the SNWA's surplus water reserves, the lower water levels in Lake Mead have also lowered its capacity to filter and dilute urban run-off and reclaimed water flows to the lake.

The combination of drought and degeneration in the wetland habitat has concentrated the potential risks of contamination from reclaimed water discharge. This highlights the importance of the environment, not only as a static receptor of effluent and biosolids from reclamation plants, but as a dynamic element that influences water resources in sometimes complex and unexpected ways (CWC, 2005: 2-28).

Figure 10: Effect of drought conditions on the Las Vegas Bay; photos from 2000, 2003, and 2005 from top to bottom respectively. (LVWCC, 2006b)

Las Vegas' Response

Decision makers within Las Vegas have pursued two complementary approaches to dealing with these environmental issues in the Las Vegas Wash. First, the 28-member governmental LVWCC was formed in 1999. It released a Comprehensive Adaptive Management plan which outlined recommendations for: (i) the installation of structures to prevent erosion, (ii) the establishment of wetlands outside of the main Wash channel; and (iii) a long-term monitoring program for water quality, aquifer testing, and shallow groundwater flow in the Wash (LVWCC, 1999: 8-15). The management plan further recommended increasing the direct reuse of reclaimed water within Las Vegas in order to reduce erosion by limiting the volume of water discharged through the Wash (LVWCC, 1999: 126).

Second, the Clean Water Coalition (CWC) is concurrently investigating alternative discharge locations in order to better manage the increasing flows of wastewater released into the Wash (CWC, 2005: CS-1). The proposed system would collect reclaimed water from the city's three reclamation plants and discharge the flow at one of three potential locations in the lower Colorado River System. This would eliminate the current situation of Las Vegas indirectly withdrawing reclaimed water from Lake Mead for potable reuse.

These two approaches illustrate how municipal agencies are enabling technical responses to environmental concerns through the creation of politically empowered committees and coalitions. These empowered groups debate different approaches to the environmental issues in order to form a consensus agenda, which is then implemented[11]. Agenda-setting through political channels enables technical groups like the LVWCC's study teams to implement solutions that can respond to the identified environmental concerns.

Risks associated with disposal of biosolid waste

Apart from reclaimed water, the second output from a reclamation plant is a residual solid material, known as sludge, which consists of organic and inorganic waste matter removed from the stream of wastewater received by the facility.

Controversy exists over whether land application of biosolids[12] constitutes a significant environmental and public health risk, suggested in several studies (Harrison and Oakes, 2002; Lewis, et al., 2002). A 2002 NRC report, "Biosolids Applied to Land: Advancing Standards and Practices," advised the adoption of scientifically based risk-assessment methods, enforcement, management practices, including environmental hazard surveillance, sampling measures, and detection procedures to reduce uncertainties around public health (NRC, 2002: 3, 6, 11).

There are specific advantages and disadvantages of landfilling, incineration, and composting biosolids. Issues which influence the selection of these methods include (i) cost, (ii) whether recycling or secondary use of the biosolids is enabled, (iii) spacing considerations, and (iv) the level of contamination of the biosolids being disposed. While there is no uniform practice for disposal of biosolids, careful disposal management is needed to ensure pathogens and inorganic contaminants are not released into the surrounding environment.

The EPA recommends Environmental Management Systems (EMS's) as a tool in mitigating the risks associated with biosolid waste disposal. An EMS prescribes a framework, or methodology, which allows an organization to develop an approach to managing and reducing environmental impacts (Stapleton et al., 2001). In the United States, the National Biosolids Partnership is a non-profit partnership involving EPA, which certifies agencies who implement an EMS and comply with the NBP requirements (National Biosolids Partnership, 2006). Certification enables a mechanism for auditing the implementation of operators' EMS to ensure they meet a standard of acceptability.

Situation in Las Vegas

The three reclamation plants in Las Vegas send treated biosolid sludge to a privately owned landfill 25 miles outside of Las Vegas (EPA, 2003). In 1994, this amounted to 600 wet tons of biosolids per day (EPA, 2003). Despite the quantity of biosolids produced and the advanced treatment operations, none of the Las Vegas facilities are certified under the National Biosolids

[11] For example, after releasing the Comprehensive Adaptive Management Plan, the LVWCC was reorganized into three active study teams dealing with Operations, Research and Environmental Monitoring, and Administrative aspects of the recommendations (LVWCC, 2006c).
[12] The use and disposal of biosolids is governed in the U.S. by "The Standards for the Use or Disposal of Sewage Sludge," otherwise known as the "Part 503 rule" (EPA, 1994b).

Partnership Certified Agency program, a program with the EPA to ensure acceptable biosolid treatment standards (National Biosolids Partnership, 2006). It is unclear to what degree these facilities use EMS measures to effectively manage their biosolids disposal strategy, safeguard public health, and protect the environment.

Centralized, Decentralized, and On-site Approaches

The scale of risk to the environment depends on the type of technology approach selected for water reclamation. For instance, centralized systems generally involve larger environmental risks due to acceptance of sewage and wastewater from a large number of users, large volume of sludge produced, and greater risk of larger-scale contamination from their reclaimed water output. Smaller scale decentralized plants may facilitate the development of artificial wetlands which accept sludge and provide environmentally beneficial opportunities to recover habitat for wildlife while biologically reducing the level of pathogens and organic contaminants in the waste (EPA, 2000; Kayombo, 2005). Local on-site treatment methods, such as composting toilets and rainwater catchment systems may also provide small-scale opportunities to reduce polluted runoff. Finally, all three systems enable the direct reuse of reclaimed water. Increasing direct reuse can reduce the total amount of water discharged through the Las Vegas Wash, which helps mitigate the effects of erosion and loss of wetland area that are currently observed with in the Wash (LVWCC, 1999: 126).

All biosolid waste from water reclamation is produced from Las Vegas' three centralized facilities. Decentralized facilities reroute their waste to the centralized plants, which are responsible for disposal of the biosolids. Given the potential environmental benefits of constructed wetlands at decentralized facilities, there may be opportunities to enable waste treatment at these smaller plants, thereby offsetting some of the waste burden placed upon the larger, centralized facilities.

Conclusion

Wastewater reclamation strategies may be constrained by environmental issues related to discharge of reclaimed water and disposal of biosolids. On the other hand, direct reuse of non-potable reclaimed water enabled by centralized, decentralized and on-site facilities may provide an environmental benefit by reducing the overall discharge of reclaimed water through the Las Vegas Wash. Additionally, developing constructed wetlands at the decentralized facilities may provide an environmentally sensitive method for the treatment of reclaimed water. In Las Vegas, agenda-setting through empowered groups has been successful in enabling implementation of the Comprehensive Adaptive Management Plan goals of protecting the environment. At an operational level, EMS systems can enable effective management of biosolids waste disposal while at the same time allowing for a system of auditing and certification that ensures an acceptable level of compliance is achieved. Both of these political and managerial tools create frameworks that enable the effective implementation of technical solutions to environmental issues.

5.4 Regulations and Incentives

Regulations and incentives are the primary instruments through which federal, state, and local governments can influence public direct reuse of reclaimed water. The current state of regulations and incentives must be considered in order to understand how supply-side issues and end-user demand for reclaimed water can be influenced through these measures.

Wastewater Reuse Regulations and Guidelines

Currently the Nevada Division of Environmental Protection (NDEP), the Nevada Division of Water Resources (NDWR), and the EPA provide guidelines and regulations to the municipal water agencies and utilities in Las Vegas to ensure proper water quality maintenance. All agencies monitor wastewater treatment and discharge through permits, inspections, and data reviews, and have specific courses of action in the event of any violation.

Federal Regulations

The EPA's Clean Water Act (CWA) of 1972 stipulated that large cities develop and implement a "208 plan," or management plan to protect water quality in the municipal area. This 208 plan is then reviewed by the EPA and NDEP to assess implementation of wastewater quality standards that effect effluent released into the environment (EPA, 2006d). Clark County adopted a 208 plan in 1998, also know as the Las Vegas Valley Water Quality Management Plan, to provide guidelines around wastewater treatment, management, reclaimed water usage, and discharge permits (CWC, 2006).

In terms of water reuse, the EPA published a set of guidelines outlining types of reuse applications, technical issues in planning water reuse systems, and various legal and regulatory issues in the 2004 report, "Guidelines for Wastewater Reclamation and Reuse" (EPA, 2004). This report is descriptive in that it highlights different state strategies around wastewater reuse, exhibited through distinct state regulations on appropriate applications of treated wastewater. However, the lack of federal regulation concerning wastewater reuse has caused a heterogeneous adoption of wastewater applications that vary by state. Also, although the EPA suggests national treatment guidelines organized by end-use, there is a large scale of treatment variability among states currently using reclaimed water (EPA, 2004: 149).

Nevada State Regulations

There are two state agencies, the NDWR and NDEP, that regulate the use, reuse, and quality of water resources in Nevada, including wastewater. The Nevada Division of Water Resources (NDWR) is responsible for the apportionment and approval of public water to protect the health and safety of Nevada citizens. The NDWR also administers water conservation programs in the state, including setting maximum quantities of wastewater that may be used for specific purposes. The second agency, the Nevada Department of Environmental Protection (NDEP), is concerned with issuing discharge permits and approving effluent management plans (EMP) to limit pollutants discharged to the environment that can also affect public health. The NDEP also establishes disinfection standards and monitoring requirements through Nevada Administrative Codes (LVVSA, 2000: 34).

In line with EPA federal guidelines around wastewater reuse, the NDEP issued an administrative code titled "The Use of Treated Effluent (Reuse) for Irrigation",[13] which lays out guidelines to protect Nevada's waters from pollutants and safeguard public health. These guidelines are accomplished through issuing permits that define acceptable treated wastewater quality,[14] management steps, and operational requirements to protect public health (LVVSA, 2000: 36).

Since issuing its original regulations around irrigating with treated wastewater, the NDEP has also proposed amendments that include additional permitted uses of treated wastewater and more clearly defined categories of wastewater treatment organized by use. By developing these wastewater treatment categories, level of treatment can be better matched with specific irrigation and non-irrigation-uses, ultimately expanding the uses of treated wastewater (NDEP, 2004).

Las Vegas Regulations

The County Sewage and Wastewater Law is a state law that establishes the Clark County Board of Commissioners (CCBC) as the local agency that deals with the collection, disposal and treatment of wastewater in Las Vegas. The CCBC enforces compliance with the 208 plan, including assuming responsibilities for technical, economic, and regulatory factors when implementing the plan. In addition, under the County Sewage and Wastewater Law, the CCBC must also consider the maximum beneficial use of water resources when conducting its 208 plan responsibilities (LVVSA, 2000: 34).

In addition to federal and state regulations, Las Vegas has employed separate regulations as a policy approach to enable the implementation of water reclamation systems. According to Section F of the landscaping regulations for Clark County and the City of Las Vegas[15], golf courses are required to use reclaimed, non-potable water for irrigation where it is available[16] (WRA, 2003). Also, new resort hotels are required to implement water saving technologies such as low-flow shower heads and toilets. Existing hotels that use potable water in decorative fountains must fund a retrofit program to offset their water usage (Hagen, 2000). Other

[13] Nevada Administrative Code 445A.275-445A.280 (State of Nevada, 2006)
[14] Wastewater quality guidelines specify fecal and total coliform levels for different irrigation applications, depending on "buffer zone distances," or distance from wastewater application area to public exposure. While all sites in Las Vegas currently irrigated with wastewater fall within a zone requiring a secondary treatment level of wastewater treatment, operating permits issued through the NDEP restricts public access in these areas. Refer to "Treatment Considerations" in Section 2.6.
[15] Clark County Resolution No. 88-002, "Resolution Establishing Rates and Regulations Governing the Storage, Sale, Charges, and Use of Treated Effluent."
[16] This contrasts with Arizona, where new golf courses may only be built if reclaimed water was available to them. (Hagen, 2000)

conservation measures pursued by the City of Las Vegas include ordinances on banning artificial lakes, restricting irrigation, and limiting landscaped turf (LVVSA, 2000: 38).

At the state, federal, and local level, regulations are in place to promote the use of wastewater technologies. The Las Vegas Valley 208 plan establishes local regulations enabled through the NDEP and NDWR to protect public health via disinfection standards and water quality monitoring. In addition to protecting public health, regulations also promote wastewater technology-use through enforcing demand-side conservation measures ultimately designed to reduce burdens on the potable water supply system. As the City of Las Vegas continues to identify uses for treated wastewater, regulations and guidelines will need to address changing technology applications to ensure that public health and environmental concerns are addressed.

Incentives through Water Pricing

Economically, the pricing of reclaimed water is critical in providing consumers with a viable alternative to offset potable water use. The Las Vegas Valley Water District (LVVWD) is the agency responsible for setting the potable water rates within Las Vegas. These rates are calculated based on a tiered pricing system for both residential and commercial users. The pricing for each tier increases based on the volume of water consumed and the size of the line inlet from the distribution system to the consumer. The rates for potable water used by commercial users in Las Vegas are shown in Table 6. (LVVWD, 2006a).

Table 6: Commercial potable water pricing tiers in Las Vegas (LVVWD, 2006a)

Meter size (inches)	**Tier**	**Consumption volume (1,000 gallons)**	**Pricing ($ / 1,000 gallons)**
1	1	0 - 12.5	$1.05
	2	12.51 - 25	$1.75
	3	25.01 - 75	$2.38
	4	75.01 and over	$3.02
1 ½	1	0 - 25	$1.05
	2	25.01 - 50	$1.75
	3	50.01 - 250	$2.38
	4	250.01 and over	$3.02
2	1	0 - 40	$1.05
	2	40.01 - 80	$1.75
	3	80.01 - 560	$2.38
	4	560.01 and over	$3.02

The current rate charged for use of reclaimed water differs across municipal agencies in the Las Vegas Valley. For instance, the City of Las Vegas sells reclaimed water to two golf courses for 23 cents per thousand gallons, while the LVVWD sell reclaimed water at $1.85 per thousand gallons (Hydroblaster, 2004; Las Vegas Golf, 2006; Grinnell, 2006). The LVVWD is expected to raise its rate for reclaimed water to $2.33 in January 2007 (Grinnell, 2006).

Regardless, these rates fall below the third potable water pricing tier. As a result, commercial customers whose water use is above the third tier have the incentive to offset their potable water use with reclaimed water. In some areas, golf operators have previously been able to negotiate reclaimed water for 80% of potable water costs, which is significant given irrigation costs can reach one million gallons annually (Huck et al, 2000).

Given these measures, Las Vegas is incentivizing the use of reclaimed water through attractive pricing, while at the same time mandating its use through legislation. In addition, the city is looking into providing incentives to developers and property owners for the installation and use of on-site water reclamation systems. (City of Las Vegas, 2005). Such incentive-based policy approaches serve to promote the use of water reclamation technologies, although the LVVWD has yet to formalize a plan outlining future specific economic and non-economic incentives.

Conclusion

Regulations at the federal, state, and local level combined with economic incentives are policy approaches that can be employed to promote the use of water reclamation technologies in Las Vegas. On the supply side, Las Vegas' 208 plan ensures the safety of reclaimed wastewater for public use, as well as reduce adverse impacts to the environment. Also, the competitive wastewater pricing plan results in an incentive regime that makes the use of reclaimed water economically attractive. On the demand side, conservation regulations and guidelines attempt to manage the demand for water and mandate the use of reclaimed water in specific applications. Although Las Vegas' current regulatory approaches encourage expansion of wastewater reuse technologies, the lack of regulatory harmonization and integration at the federal level creates a patchwork of guidelines that is potentially vulnerable to redundancies, gaps in coverage, and inefficiencies, which might impede the implementation of water reclamation technologies.

5.5 Security

The security of a region's water infrastructure is of critical importance, and has been even more of a high profile issue since September 11, 2001. In response to those attacks, Nevada passed a water security bill in 2003 that requires each water utility to conduct a vulnerability assessment as well as prepare and maintain an emergency response plan in accordance with national guidelines. Water utilities are also required to review their vulnerability assessments and emergency response plans at least once a year (Atkins and Morandi, 2003). Furthermore, Nevada joined 36 other states in amending its Freedom of Information Act (FOIA) to exempt water system security information (e.g. vulnerability assessments) from public disclosure requirements. In terms of water reclamation and reuse, Nevada does not have specific state guidelines concerning these facilities.

Centralized, Decentralized and On-site Approaches

Apart from the regulatory considerations around water security, the large centralized wastewater facilities in the Las Vegas region represent high-value targets, as their disruption can have a large affect on water supply to the entire region. Failures in decentralized systems, on the other hand, have limited impacts as the regions they service are far smaller. In this way, onsite and decentralized facilities provide a robust and resilient system that inherently mitigates risks to water security in a region. At the same time, security risks at centralized facilities can be somewhat mitigated through increased measures to protect these facilities from inadvertent failure and purposeful malicious attacks.

Conclusion

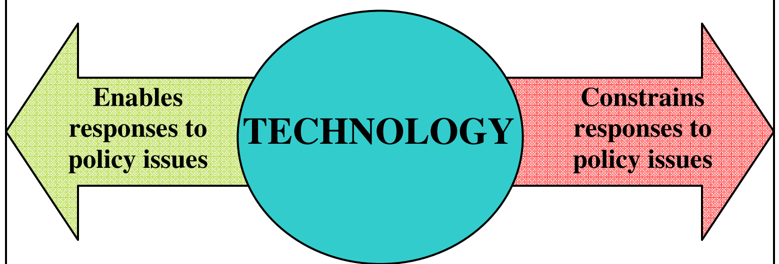
Security concerns can favor the implementation of decentralized or on-site plants over centralized plants. Las Vegas appears to be aware of the issues surrounding the security of its water infrastructure, and is taking steps to strengthen it. By diversifying the technologies used for water reclamation and reuse, Las Vegas is also making the entire water treatment and distribution network more robust by reducing the single-point nodes of potential failure. As more decentralized reclamation plants come on line, the water system will become even more resilient, which is of critical importance as region’s water resources become more and more strained.

5.6 Summary of Technology and Policy Interactions

Figure 11 summarizes the interplay of technology and policy issues in water reclamation discussed in this report, namely those highlighted in this section and distribution issues examined earlier in the report. Specifically, Figure 11 presents how technology could enable or restrain responses or solutions to policy considerations in water reclamation; as well as how policy issues could enable or constrain the implementation of water reclamation technologies.

Figure 11: Summary Map of Technology and Policy Interactions

- Advanced water reclamation technologies can mitigate health risks of reclaimed water. (H)
- Technologies that enable public access to continuous water monitoring information increase trust, provide health assurances for reclaimed water. (H, P)
- Decentralized systems enable environmentally beneficial constructed wetlands. (E)
- Interconnected, smaller-scale of decentralized, on-site systems enables protection against wide-spread health issues, environmental impacts, and water security risk in case of failure. (H,E,S)
- Flexible combination of centralized, decentralized, on-site systems enables best fit with end user demands. (D)

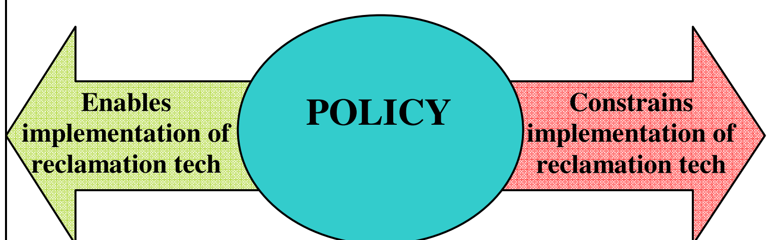


- Uncertainties in risk assessment, health and safety testing, water quality monitoring, system reliability of reclamation systems constrain indirect potable reuse of reclaimed water. (H)
- Large through-put at centralized reclamation technological systems pose larger health risks, constrain indirect potable reuse of reclaimed water. (H)
- Discharge of reclaimed water poses health, environmental risks which constrain potable reuse of reclaimed water. (E, H)
- Disposal of biosolids poses health, environmental risks which constrain disposal options. (E, H)

<u>Legend for types of issues:</u>

P – Perception
H – Health
E – Environment
R – Regulation
S – Security
D – Distribution

- Definition of a vision through issue framing enables implementation of water management technologies. (D)
- Early empowerment of stakeholders, use of agenda-setting through committees increases support for water reclamation technologies. (P, H, E)
- Public education promotes awareness, enabling positive perception of reclamation techs. (P)
- Incentives improve end-user perception & participation, enabling use of reclamation techs (P, R)
- EMS enable control over environmental impacts in operation of reclamation plants. (E)
- Regulations mandating use of reclaimed water at golf courses enable end-user demand for reclaimed water. (R)



- Public perception of health risks creates opposition which limits use of reclamation techs. (P)
- High costs of advanced treatment technologies that mitigate health risks constrain their use. (H)
- Lack of harmonization in regulatory approaches causes inefficiencies which constrain implementation of water reclamation technologies. (R)
- High cost of dual-distribution infrastructure constrain availability of nonpotable reclaimed water for direct reuse. (D)

6

Conclusions, Best Practices, and Recommendations

6.1 Conclusions

Given Las Vegas' location in a water-constrained area, coupled with its primary reliance on a 4.5% allocation of Colorado River water, the city faces unique challenges in securing a safe, reliable water supply into the future. Las Vegas' water challenge is exacerbated by large population growth amidst a time of the worst drought in its history. At the same time, the city produces the cleanest reclaimed water in the U.S., and is engaging in innovative solutions to secure additional resources through negotiations with neighboring states, and the development of additional groundwater and surface water resources. In addition, extensive water conservation measures have been implemented to manage increasing water demands. Water reclamation is one such measure.

Within this context, water reclamation will play an increasingly important role for Las Vegas. Las Vegas is currently discharging most of its highly treated effluent to Lake Mead for return flow credits, enabling more withdrawals from the Colorado River – a practice of unplanned indirect potable reuse. Additionally, reclamation is helping to offset potable water demands through Las Vegas' combined system of water reclamation facilities. These include centralized facilities and smaller decentralized treatment plants which directly supply non-potable reclaimed water to golf courses and other large point source users; as well as on-site water reclamation systems used by smaller-scale point source users like hotels and resorts. As Las Vegas develops its in-state water resources, which are not eligible for return flow credits, such direct non-potable water reuse will further increase in importance.

However, implementing and using reclaimed wastewater systems as a water resource raises crucial policy issues that can either support or hinder the adoption and promotion of wastewater technologies. This report has identified stakeholder groups with vested interests in the Las Vegas water supply and addressed the interplay between policies affecting public perception, human health, environment, regulation and incentives, and security and the utilization of wastewater technologies. Major findings include:

- Las Vegas has used a flexible combination of centralized, decentralized, and on-site technology scales in order to meet the various demand requirements of end-users such as golf courses, resorts, hotels, and parks;
- While the city is pursuing a broad range of different strategies, there is no evidence of a deliberate attempt to frame the role of water reclamation within a overarching vision of water resource management;
- Las Vegas appears successful in enabling reclamation technologies by the implementation of comprehensive public communication programs, including outreach and education, to overcome potential perception barriers of multi-stakeholder groups;

- Ensuring human health requires policies that establish a robust system of management and safeguards in order to mitigate risk and uncertainty to an appropriate level;
- Wastewater technology support may be constrained due to environmental issues of discharge of reclaimed water in the Las Vegas Wash and disposal of biosolids. In Las Vegas, agenda-setting through empowered groups, system auditing tools, and certification has great potential in enabling implementation of policy goals of environmental protection within the wash;
- Demand and supply-side regulations at the federal, state, and local level combined with economic incentives are policy approaches that can promote the use of water reclamation technologies in Las Vegas. However, the lack of regulatory harmonization and integration at the federal level creates piecemeal guidelines that are potentially vulnerable to gaps in coverage and inefficiencies, and can impede the implementation of water reclamation technologies; and
- Security concerns may favor the implementation of smaller versus large scale technologies. By diversifying the technologies used for water reclamation and reuse, Las Vegas is creating a more robust water treatment and distribution network by reducing the number of single-point nodes of potential failure.

The comprehensive consideration given in the preceding sections of these five policy issues and their influence on the acceptance of wastewater reclamation technologies led the committee to develop recommendations and best practices for Las Vegas and more generally, the U.S. The following sections outline these recommendations and best practices derived from the case study.

6.2 Best Practices

From the Las Vegas case study, the committee developed a set of generalized best practices for the implementation of water reclamation projects in the United States. Appropriate channels, powers, resources, and windows for implementation of these practices have been identified, where possible. These practices are summarized by the implementation tool included in Table 7.

PRACTICE 1: Issue framing is critical in developing successful wastewater reclamation and reuse programs and should be given specific attention through a formalized process.

The main purpose of issue framing should be to articulate an overarching vision to communicate the goals and bounds of water resource management. This process should recognize that the underlying castings, assumptions, and biases of different stakeholders can influence solutions to water management challenges.

Issue framing processes can use internal institutional channels between government actors to develop a vision among decision-makers. In addition, grassroots channels can mobilize external stakeholders, and media channels can be leveraged to effectively communicate the vision of water resource management to the public. Utilizing these different channels gives decision-makers the power to set ground rules and convey their perception of the issue. At the same time, it allows stakeholders to provide their ideas and either accept or object to the vision. The use of media resources to communicate this vision grants these agencies the power to interpret and disseminate this vision to the general public. Ideally, the process will generate greater alignment among diverse groups on issues, such as water reclamation, which are heavily influenced by the perceptions and acceptance of stakeholder groups.

Stakeholder participation is likely most important in areas where water resources are scarce, or where environmental conditions, such as drought, affect the availability of water. For example, Las Vegas' location in a water scarce region and the current state of drought in the area have heightened public interest in water issues and the role of water reclamation. These environmental conditions provide windows through which decision-makers may be able to leverage interest and input in issue framing strategies across a number of diverse interests and stakeholders.

PRACITICE 2: Identify key stakeholders and involve them early in the decision-making process.

Stakeholder analysis and mapping tools can be used to identify key public stakeholders in water reclamation projects. These key stakeholders should be engaged early in the decision-making process and be empowered to make an informed decision on water reuse.

Similar to the practice of issue framing, institutional channels can be used to identify stakeholders and develop a process for engagement. Grassroots channels offer a route to mobilize participation within the public and industry, allowing the development of processes for identification and engagement. Finally, the process can be communicated through media channels to the broader public.

The most appropriate window for engagement of stakeholders is at the outset of a decision-making process. This gives the process credibility, and empowers the involved stakeholders to make genuine recommendations on how planning and strategies should proceed.

PRACTICE 3: Conduct extensive public education, with transparency in the dissemination of information on the benefits and risks associated with water reclamation projects.

It is important to complement direct stakeholder involvement with extensive public outreach and education to increase awareness of the benefits and risks of water reclamation and reduce opposition due to misconceptions or ungrounded fears. Such public communication processes should be transparent and information provided should be accurate, complete, and updated regularly.

Media management is an important part of this communication effort as it is the main channel through which the public receives information on the project. A public relations office can also be set up by the lead organization to create informative web-pages, publish newsletters, and answer queries from the public. This allows decision-makers to access communication resources, but grants media the power to interpret the messages of city and state officials. Grassroots channels provide another way to communicate information on water reclamation to the public, perhaps through public town-hall meetings, allowing site tours of public reclamation facilities, or other community engagement practices.

PRACTICE 4: Develop an incentive-based framework to promote wastewater reuse.

The provision of economic incentives is important in promoting the use of recycled water, particularly among economically-motivated commercial customers. For example, a component of an incentive-based system could be to increase the price of treated potable water, while decreasing the price of recycled non-potable water. In Las Vegas, reclaimed water is priced competitively, which encourages its use among commercial customers. This effect is offset somewhat by water quality issues, particularly amongst golf course operators. However, the city recognizes the importance of providing incentives to developers and property owners, and is planning measures to promote the use of on-site water reclamation systems.

Institutional or legislative channels might be used to develop a robust strategy to incent wastewater reuse. Government actors have the means to implement attractive pricing plans for reclaimed water, and legislative channels may be employed to provide financial incentives (e.g. tax rebates) for the use of reclaimed water. These financial incentives use market channels that harness economic power to influence stakeholders. At the same time, industry stakeholders have the collective power to support financial incentives, or to lobby for more generous instruments.

Fiscal and legislative cycles provide opportunities for the enactment of fiscal incentives. For example, incentives can be announced with the tabling of a new budget proposal, or as part of a political campaign during an election. These political cycles can also provide windows in which industrial stakeholders lobby for the enactment of specific measures to incent the use of reclaimed water.

PRACTICE 5: Consider the implementation of a combination of different wastewater reclamation and reuse systems based on specific demand requirements from end-users.

A combination of reclamation systems, consisting of centralized facilities, decentralized facilities, and on-site reuse systems, provides a robust solution to meet the demand-side requirements of end users in an area.

This hybrid approach is one that can be encouraged at many levels. Municipal governments have the ability to mandate the scale of reclamation facilities, and should do so. Urban planners should be educated about the benefits of using a combination of reclamation facility scales so that they can optimally position them according to best use practices. Since municipal contractors and utilities will build and operate the facilities, they, too will require education regarding the benefits of using multi-scale facilities within the same municipality.

There are many opportunities to implement hybrid systems. Droughts and other water-related environmental crises can provide the political will to fund these systems. Expansion of the water system infrastructure is also an opportune time to transition to a hybrid system, especially when decentralized and on-site plants are shown to provide service to underserved communities. The retirement of municipal utility officials accustomed to centralized water reclamation and distribution provides a great opportunity to involve administrators in who are amenable to decentralized plants.

PRACTICE 6: Implement environmental management systems, such as EMS under ISO 14000 to quantify, manage, and mitigate environmental risks associated with water reclamation practices.

Due to environmental issues associated with the inappropriate discharge or reuse of reclaimed water, or improper disposal of biosolids, EMS' are important in providing a framework for monitoring and mitigating the environmental risks of these practices. Additionally, EMS' provide a level of accountability to the public, which can increase trust and acceptance of reclamation practices.

The use of auditing and certification agencies, such as the National Biosolids Partnership, may be effective institutional and administrative channels with which to encourage the use of EMS in water reclamation. Additionally, media channels can play an important role in communicating the relevance of EMS' and certification to external stakeholders. Finally, public understanding and acceptance of EMS' and certification agencies can be obtained through grassroots channels, which ideally increase the level of trust through the accountability of operators to external stakeholder groups.

Public events such as the commissioning of new water reclamation infrastructure provide windows to positively stress the benefits of EMS and certification programs. At the same time, negative events such as public environmental controversies, from either water reclamation or other practices, can provide opportunities to explain the importance of EMS systems, and their role in protecting the environment from further harm.

Table 7: Summary of best practices and tools for implementation

NO.	BEST PRACTICE	CHANNELS	POWERS / RESOURCES	WINDOWS
Policy-Based Practices				
1	Use issue framing to develop an overarching vision for water management.	Institutional Grassroots Media	• State / municipal government: power of influence, ground-rules for developing vision. • Public: resource of ideas; power of acceptance or objection • Media: power to interpret vision; communication resources	• Environmental conditions: water scarcity, drought
2	Identify stakeholders and involve them early in the decision-making process	Institutional Grassroots Media	• State / municipal government: power of influence, selection of stakeholders, rule-making • Public: resource of ideas; power of accepting, stonewalling, or objecting to the process. • Media: power to interpret results; communication resources	• At the outset of a planning or decision-making process
3	Conduct public education and ensure transparency in dissemination of information on water reclamation.	Media Grassroots	• State / municipal government: power of persuasion, creation of materials; education resources, sharing success stories • Media: power to interpret messages; communication resources.	• Infrastructure expansion or replacement • Water scarcity, drought • Improvements in wastewater treatment technology
4	Implement an incentive-based framework to promote wastewater reuse.	Institutional Legislative Market Industrial	• State / municipal government: Monetary resources; power to enact incentives, rule-making • Market: power of market forces • Industry, public: power of acceptance, buy-in or rejection of measures	• Fiscal cycles, "legislative" cycles • Infrastructure expansion or replacement
Technology-based Practices				
5	Consider a combination of water reclamation systems to meet demand requirements of end-users.	Institutional Administrative Industrial	• State / municipal government: power of rule-making; monetary and planning resources; resources to forecast future water demand from end-users • Industry: resources for infrastructure development	• Environmental conditions: water scarcity, drought • Change in leadership • Infrastructure expansion or replacement
6	Implement EMS to monitor and mitigate the environmental risks of water reclamation.	Institutional Administrative Media	• ISO: EMS resources, power of certification • National Biosolids Partnership: auditing resources, power of certification • Media: resources for communication of EMS and certification • Public: power of trust and acceptance in certification process	• Commissioning of new infrastructure • Environmental scares

6.3 Recommendations

In addition to the best practices described above, the committee also identified a set of recommendations applicable to the national water reclamation community. Potential channels, powers, resources, and windows for implementing recommendations are identified to enable implementation of these measures. The summarized recommendations and potential implementation tools are summarized in Table 8.

RECOMMENDATION: The committee recommends the establishment of an entity within the EPA to work closely with states and local municipalities to advance and support wastewater reclamation.

This entity will provide a comprehensive service for local agencies considering the implementation or expansion of wastewater reclamation projects. In addition to serving as a clearinghouse on current regulatory, technological, health, and environmental considerations in wastewater reclamation, this entity will work with relevant authorities to establish or review national policies, guidelines and strategies to advance efforts in wastewater reclamation.

The most appropriate channels for this level of wastewater program support include regulatory, administrative, and educational approaches. The role of an existing entity such as the Office of Wastewater Management within the EPA could be expanded to collect, maintain, and distribute information on wastewater reclamation and reuse. Using this branch within the EPA, information from national wastewater consortiums, local coalitions and municipal utility operators would be shared and promote nationwide, multi-sector visibility.

A wealth of information currently exists at the state and local level on wastewater reclamation and reuse projects that could beneficially serve other entities if disseminated. As an increasing number of states and municipalities begin to implement, update, or enlarge wastewater projects, a centralized source of materials housed within the EPA would insure that quality information addressing all critical technical and policy issues is available. Providing this accessibility of information through a national agency is a logical step in advancing and supporting wastewater reclamation and reuse as water becomes an increasingly valuable commodity.

RECOMMENDATION: The committee recommends that EPA develop and coordinate guidelines for state and municipal wastewater treatment and distribution regulations organized by non-potable end use to address any analysis gaps.

Guidelines for developing wastewater treatment regulations should be prepared by the EPA based on final application of non-potable water. Non-potable reuse projects can manage regulated contaminants by adhering to proposed regulations' guidelines, allowing states currently utilizing non-potable water to safely pursue these projects.

State regulations for wastewater project development based on end-use are largely inconsistent due to gaps in state and federal regulation. EPA should work closely with states and municipalities to establish uniform design, construction, operation, and maintenance guidelines to minimize variability in program implementation and processes. These guidelines, if adopted, can help a state organize its utilities treatment and distribution systems by unifying the fragmented requirements of local, state, and federal regulation. Given the variability of current wastewater programs and the level of treatment discrepancies between states and municipalities, integration of wastewater system guidelines should occur on a federal level to insure wastewater treatment and distribution components are standardized through regulation.

The final application of treated wastewater, different standards, codes, and regulatory programs create uncertainties around public health. While there have been no public health outbreaks to date stemming from non-potable wastewater reuse, information around wastewater system design and management needs to be integrated, standardized, and promulgated given the increasing numbers of states and municipalities pursuing these reuse programs.

RECOMMENDATION: The committee recommends the development of a Health Management System framework to facilitate control, auditing, and the quantification of uncertain health risks in water reclamation.

Although management systems are not sufficient to guarantee public safety, a comprehensive framework for control and assessment can help mitigate serious health risks. These systems should, at minimum, include preliminary risk assessment, water quality monitoring, health and safety testing, and the evaluation of overall system reliability (NRC, 1998: 3). In contrast to EMS, there are currently no equivalent frameworks for similar control of health risks.

Administrative channels provide an effective means for realizing this objective. Similar to the concept of EMS’, developing a health management framework would allow individual operators to voluntarily implement an appropriate management system without the creation of an excessively binding or prescriptive regulation. Given its power of authority and existing EMS resources, the EPA should consider drafting a guideline that outlines the recommended elements of a Health Management System. In addition to this guideline, an auditing program, similar to the model currently used by the National Biosolids Partnership, should be developed to certify operator’s management systems and ensure they meet an acceptable standard. Such a certification program would leverage the power of public perception and acceptance in order to increase stakeholders’ trust in the operators, and strengthen an operator’s level of accountability to the public.

The current lack of an authoritative health management framework is a major weakness in water reclamation strategies, particularly in places such as Las Vegas, where the practice of unplanned indirect potable reuse occurs. A widespread health scare from the risks of public consumption of reclaimed water would provide a window of opportunity to implement health management systems. Due to the negative repercussions of a public health emergency, the use of this window is not recommended; some level of action should be taken to avoid widespread public health issues.

Table 8: Summary of recommendations and implementation tools.

NO.	RECOMMENDATION	CHANNELS	POWERS / RESOURCES	WINDOWS
1	Establishment of an entity within the EPA to work closely with states and local municipalities to advance and support wastewater reclamation	Administrative Legislative Institutional Educational	• Legislative: EPA, State environmental agencies: power to steer national wastewater agenda and regulate • Administrative: Local water authorities, influence wastewater implementation • Water utilities: Power to oversee operations • National/local coalitions: Encourage educational resources around wastewater technology	• Health and environmental scares • Increased adoption of wastewater technology • Improvements in wastewater technologies
2	Development and coordination of state and municipal guidelines via EPA for wastewater treatment and distribution system regulations organized by non-potable end use to address any analysis gaps	Administrative Institutional Legislative	• Legislative: EPA, State environmental agencies: authority to regulate • Administrative: Local water authorities, power to permit, influence regulations • Water utilities: Power to oversee wastewater management operations	• Health and environmental scares • Drought • Exploration of new non-potable uses
3	Development of a Health Management System framework to facilitate control, auditing, and the quantification of uncertain health risks in water reclamation	Legislative Administrative Institutional Media	• Legislative: power to regulate • Administrative: power to assess and audit • Public: power of trust and acceptance in certification process • Media: resources for communication of HMS and certification	• Health scares • Increased adoption of wastewater technology

Future Research

The tools and frameworks to evaluate the efficacy of hybrid wastewater reclamation and reuse systems need to be developed.

While it is common practice to assess one centralized wastewater reclamation, treatment, and distribution technologies against another one, it is not clear what methods and metrics should be used to evaluate a hybrid system consisting of several facilities at the on-site, decentralized, and centralized scales. Due to different treatment technologies and collection and distribution methods across the range of scales, an appropriate metric for an on-site facility, for example, will rarely be meaningful for a centralized plant. Without integrated, consistent evaluative metrics pertaining to the efficiency and effectiveness of the system as a whole, it will be difficult to decide where to invest in new infrastructure and determine how well existing systems are performing. These metrics need to encompass the system as a whole, including wastewater sources, treatment technologies, distribution methods, and end-use.

There is an urgent need for further research on water quality monitoring and treatment, specifically with regards to: (i) estimating risks to health and the environment, (ii) the long term health effects of contaminants in reclaimed water, (iii) detection and monitoring of pathogen levels in reclaimed water, and (iv) methods for assessing and improving water reclamation system reliability.

Despite the efficacy of advanced water treatment processes, there are inherent uncertainties in the effectiveness and reliability of these systems. As a result, further research is essential in mitigating the risks to human health posed by indirect reuse of potable water.

Annotated Bibliography

(Archuleta, 2004) Archuleta, Peter (2004) Nevada Views: Helping to conserve, Las Vegas Review Journal, May 30, 2004.

This article highlights the importance of water reclamation and the potential to increase direct non-potable reuse in Clark County. This source was used to provide a sense of the sentiments of Las Vegas citizens towards water reclamation.

(Asano and Cotruvo, 2004) Asano, T., & Cotruvo, J. A. (2004). Groundwater recharge with reclaimed municipal wastewater: health and regulatory considerations. *Water Research, 38*(8), 1941-1951.

In this peer-reviewed article, Asano and Cotruvo focus on the health and regulatory aspects of groundwater recharge of reclaimed wastewater. The article outlines some uncertainties with respect to health risks, and draws upon the State of California's criteria for groundwater recharge and the World Health Organization's *Guidelines for Drinking Water* as examples of cautious approaches to setting guidelines. This summary article informed the study of health issues and uncertainties in state of the art water reclamation technologies.

(Atkins and Morandi, 2003) Atkins, Cathy; Morandi, Larry (2003) Protecting Water System Security Information, *Water Security*, National Conference of State Legislature.

This report provides an analysis of the legislations governing water security across different states in the U.S. following September 11 attacks. This source provided information on the regulations in Nevada governing water infrastructure security.

(Bazza, 2003) Bazza, M. (2003). Wastewater recycling and reuse in the Near East Region: experience and issues. *Water Science and Technology: Water Supply*, 3(4), 33-50.

This peer-reviewed article examined the key policy issues affecting water reclamation and reuse in the Near East, as well as analysed how these policy issues came into play in specific countries in this region. This article provided some background on prior studies that have been conducted on water reclamation issues.

(Bureau of Reclamation, 2003) Bureau of Reclamation. (2003). Water 2025: Preventing Crises and Conflict in the West. Press release. U.S. Department of the Interior, Bureau of Reclamation. Retrieved November 4 2006, from http://www.doi.gov/water2025/news/news5-2-03.html

This governmental press release announced the release of the Water 2025 proposal from Secretary Gale Ann Norton of the Bureau of Reclamation. The release emphasizes the importance of water supply challenges in the West, and identifies Las Vegas as a water constrained area. This source was used to set the context for choosing Las Vegas for our case study.

(Bureau of Reclamation, 2006) Bureau of Reclamation Website. Retrieved November 4 2006, from http://www.usbr.gov/.

This is the main webage of the Bureau of Reclamation in the U.S. Department of the Interior. This website offers authoritative and current information on the Bureau of Reclamation's activities. This source was used to gather preliminary information on the Bureau of Reclamation for the report's survey of stakeholders.

(Bureau of Reclamation, 2006a) Bureau of Reclamation Website. Retrieved November 4 2006, from http://www.usbr.gov/main/about/.

This website contains authoritative information provided by the Bureau of Reclamation on its history, jurisdiction, mission, and scope of operations. The information presented on this page was used to form analysis of the Bureau's mission, motivation, power and influence for the survey of stakeholders in the report.

(Brean, 2004) Brean, Henry (2004) Reclaimed water seen as wave of future. Las Vegas Review-Journal, May 26, 2004.

This article describes Clark County Water Reclamation District's plan to expand the provision of reclaimed non-potable water to users such as golf courses, public parks and schools. The information in this article provided information on Clark County Reclamation District's non-potable water customers, as well as its infrastructural expansion plan and cost in the report.

(CCWRD, 2006) Clark Country Water Reclamation District (CCWRD) (2006) Water Reclamation. Accessed on Nov 5, 2006 from http://www.cleanwaterteam.com/waterreclamation.html

This webpage of Clark County Water Reclamation District provides a message to the public on the importance of water reclamation in Las Vegas, and the efforts CCWRD has put forth to involve the public in the implementation of water reclamation projects. It also provides information on CCWRD and their core values and beliefs in water reclamation. This webiste was used to provide information on the roles and missions of CCWRD for the stakeholder analysis of the report.

(CCWRD, 2006a) Clark County Water Reclamation District (CCWRD) (2006a) Desert Breeze Water Reclamation Facility. Accessed November 5 2006 from http://www.cleanwaterteam.com/desertbreezefacility.html.

This webpage provides information on the Desert Breeze Water Reclamation Facility, a decentralized reclamation plant in the Las Vegas area. The webpage is published by the facility's operator, the CCWRD, and is designed for viewing by the general public. This source was used to gather information on the Desert Breeze facility and the state of decentralized reclamation in Las Vegas.

(CCWRD, 2006b) Clark Country Water Reclamation District (CCWRD) (2006) Our Mission. Accessed on November 17, 2006 from http://www.cleanwaterteam.com/mission.html

This webpage provides a simple statement of the CCWRD's mission for use by the general public. It was used to gather information on the CCWRD's mission and core beliefs for the survey of stakeholders.

(CCWRD, 2006c) Clark Country Water Reclamation District (CCWRD) (2006) Wastewater Treatment . Accessed on November 17, 2006 from http://www.cleanwaterteam.com/wastewatertreatment.html

This webpage provides a summary of the CCWRD's beliefs with regards to wastewater reclamation. The page is designed to inform members of the general public. The source was used to gather information on the CCWRD's core beliefs and values in this report's stakeholder survey.

(CCWRD, 2006d) Clark County Water Reclamation District (CCWRD) (2006d) District Facilities: Main Facility. Accessed November 5 2006 from http://www.cleanwaterteam.com/mainfacility.html.

This webpage provides information for the general public on the treatment capacity of the CCWRD's centralized facility in Las Vegas. This treatment capacity was used to compare the scale of the CCWRD's plant with the other centralized facilities in Las Vegas in the table of water reclamation facilities in Section 2 of the report.

(CityCenter, 2006) City Center Website. (2006) Accessed on November 10, 2006 from http://www.citycenter.com/

This is the website of CityCenter, a new resort that will be built on the Las Vegas strip in the next 5 years. This resort will be implementing an on-site water reclamation system.

(City of Henderson, 2006) City of Henderson (2006) Utility Services. Accessed on November 18, 2006 from http://www.cityofhenderson.com/utilities/php/utilitiesbody.php

This website is managed by the City of Henderson, and provides information on the agency's mission and objectives. The page is designed for use by the general public to gather information on the plant. It was used to determine the City of Henderson's mission for the survery of stakeholders.

(City of Henderson, 2006a) City of Henderson (2006) City of Henderson Water Reclamation Facility. Accessed on December 1, 2006 from http://www.ci.henderson.nc.us/Water_Reclamation/Default.asp

This website by the City of Henderson, and provides information on the city's water reclamation facility. This site was used to determine the first date of operation of City of Henderson's water reclamation facility.

(City of Las Vegas, 2006) City of Las Vegas (2006) Public Works Department website. Accessed on November 22, 2006 from http://www.lasvegasnevada.gov/information/5397.htm.

This webpage is managed by the City of Las Vegas in order to inform the general public. It provides a summary of the Public Works Department's mission and responsibilities in wastewater treatment. This source was used to develop the stakeholder survey table used in the report.

(City of Las Vegas, 2006a) City of Las Vegas (2006) Water Pollution Control Facility. Accessed on December 1, 2006 from http://www.lasvegasnevada.gov/files/BRO-WPCF_04.pdf

This is a brochure on the Water Pollution Control Facility, the centralized water reclamation facility in Las Vegas to provide to the public information on the facility's history and treatment facilities. This brochure was used in the report to provide information on the Water Pollution Control Facility, such as its capacity, sources and distribution of wastewater.

(City of Las Vegas, 2006b) City of Las Vegas (2006) Durango Hills Water Resource Center Brochure. Accessed on December 1, 2006 from http://www.lasvegasnevada.gov/files/NWwaterresourcecenter.pdf

This is a brochure on the Durango Hills Water Resource Center, the decentralized water reclamation facility in Las Vegas to provide to the public information on the center's treatment facilities. This brochure was used in the report to provide information on the Durango Hills Water Resource Center, such as its capacity, sources and distribution of wastewater.

(City of Las Vegas, 2006c) City of Las Vegas (2006) Fun Statistics on Las Vegas. Accessed on November 22, 2006, from http://www.lasvegasnevada.gov/FactsStatistics/funfacts.htm

This "fun facts" source is a tourism website for the City of Las Vegas which provides facts of information regarding its demographics and history. Specifically this site provided a statistic on the number of people moving to the Las Vegas area on a monthly basis and contributed to the "Current State" section of the report that highlights population growth.
http://www.lasvegasnevada.gov/FactsStatistics/funfacts.htm

(City of Las Vegas, 2005) City of Las Vegas (2005) The City of Las Vegas Water Element of the Las Vegas 2020 Master Plan

This document describes the goals, objectives and policies in Las Vegas' 2020 Master Plan on water resources. This reference was used to gain an understanding of Las Vegas' position and policies on water reclamation.

(CWSD, 2006) Cottonwood Water and Sanitation District (CWSD) (2006) Indirect Potable Reuse, Table of Contents, Article Summaries / Case Studies. Accessed on November 26, 2006 from http://www.cottonwoodwater.org/indirect_potable_reuse.htm#09

This CWSD webpage provides brief summaries of case studies on the use of recycled water, including economic, perception, regulatory, technical perspectives of different cases. Las Vegas is one of the cases mentioned, and the focus is on how Las Vegas managed public perception issues in the implementation of its watewater reclamation plant.

(CWC, 2005) Clean Water Coalition (CWC). (2005). Clean Water Coalition Systems Conveyance and Operations Program Environmental Impact Statement. Retrieved October 29 2006, from http://www.cleanwatercoalition.com/EIS/documents/CWCDEIS-Frontitemsandchapters.pdf

This is an extensive Environmental Impact Survey vetted through the Clean Water Coalition's members and opened to public comments. This information was used to determine future plans for relocating the City of Las Vegas' reclaimed water discharge outlet to one of three different locations. It informed the environment section of the report, particularly with respect to the understanding of the environment as a dynamic element influencing water resources.

(CWC, 2006) Clean Water Coalition (2006) Media Update. Accessed October 25, 2006 from http://www.ci.north-las-vegas.nv.us/Departments/Utilities/PDFs/UtilityOperations/CWCMediaUpdate.pdf

This document is a Media Update published by the Clean Water Coalition (CWC) that explains this history of the CWC, issues around discharging into the Las Vegas Wash, regulatory and permitting issues around wastewater effluent, including discussion of Clark County’s 208 plan, and the use of reclaimed water. This update also frames the importance of public acceptance, education, and outreach programs in wastewater reclamation strategies as well as the importance of optimally locating reclamation facilities to serve customers.

(CWC, 2006a) Clean Water Coalition (CWC). (2006). Clean Water Coalition Website. Retrieved October 29 2006, from http://www.cleanwatercoalition.com/

This website maintained by the Clean Water Coalition provides information on their roles in reclaimed water discharge and reuse, as well as the establishment and roles of the Citizens Advisory Committee. This website also provided information on the high standard of wastewater treatment in Las Vegas. This website was used extensively in the report to understand the roles, missions, values and current projects of CWC in wastewater reclamation, as well as how they engaged and empowered public stakeholders in their Citizen Advisory Commitee.

(CWT, 2006) The Clean Water Team (2006) Uses. Accessed on December 1, 2006 from http://www.therightwater.com/uses/

The website by the Clark County Water Reclamation District provides information on the potential uses of reclaimed water based on the uses of the customers it services. This information was used to determine the customers of the reclamation district in the report.

(EPA, 1994) Environmental Protection Agency (EPA) (1994) Land application of sewage sludge a guide for land appliers on the requirements of the federal standards for the use or disposal of sewage sludge, 40 CFR part 503. from http://purl.access.gpo.gov/GPO/LPS45673

This is the EPA's authoritative guide that specifies appropriate practices for land application of sewage sludge. The Part 503 guideline was cited for reference in the environment section of the report.

(EPA, 2000) Environmental Protection Agency (EPA) (2000) Guiding Principles for Constructed Treatment Wetlands.

This document is a guidance paper that specifies principles for developing constructed wetlands for water treatment. It is a relatively authoritive resource endorsed by the Natural Resources Conservation Services, the U.S. Fish and Wildlife Service, the National Marnie Fisheries Service, the U.S. Bureau of Reclamation, and the U.S. Army Corps of Engineers. This paper was cited to elaborate on environmental benefits provided by decentralized reclamation facilities that use constructed wetlands to treat effluent.

(EPA, 2003) Environmental Protection Agency (EPA) (2003). Biosolids Technology Fact Sheet: Use of Landfilling for Biosolids Management. Retrieved November 3, 2006, from http://www.epa.gov/owm/mtb/landfilling_biosolids.pdf

This briefing fact sheet was produced by the EPA to provide concise information on landfilling for biosolids disposal. The document cites its primary data sources, allowing for verification of the information provided. It was cited in the report to demonstrate how Las Vegas handles its biosolids waste, and the volume of waste generated from the city's reclamation facilities.

(EPA, 2004) Environmental Protection Agency (EPA) (2004). Guidelines for Water Reuse. Retrieved October 28 2006, from http://www.epa.gov/nrmrl/pubs/625r04108/625r04108.pdf

This report provided extensive information on wastewater reclamation and reuse guidelines in the U.S. and internationally, including end-use applications, technical planning considerations around wastewater reclamation infrastructure, and an assessment of U.S. state guidelines and regulations around wastewater technologies. The information was used primarily in the “Current State” section of the report to describe treatment technologies and technical issues around dual-distribution water systems, and also mentioned in the Regulation section within the Policy Issues discussion.http://www.epa.gov/owm/mtb/incineration_biosolids.pdf

(EPA, 2006a) Environmental Protection Agency (EPA) (2006). Water Recycling and Reuse - Water - Region 9 - EPA. Retrieved 26.October 2006, from http://www.epa.gov/Region9/water/recycling/index.html

This webpage provides a general overview of water recycling in a non-technical format. It describes what water recycling entails and the different benefits that it provides. This resource was used in the document to show the benefits water reclamation can provide to the natural environment.

(EPA, 2006d) Environmental Protection Agency (EPA) (2006) Water Quality Standards Program History. Accessed November 2, 2006 from http://www.epa.gov/waterscience/standards/about/history.htm

This website provides a history of the evolution of water quality standards in the U.S., specifically discussing the role of the EPA in developing rules, regulations, statues, and guidelines around wastewater pollutants. The site also discusses the regulatory relationship between the EPA and States and Tribes in determining policy around water effluent. Used in the Regulation section, this site provided information about the relationship between the EPA and state departments of environmental protection.

(EPA, 2006e) Environmental Protection Agency (EPA) (2006) Our Mission; What We Do. Accessed November 18, 2006 from http://www.epa.gov/epahome/aboutepa.htm

This website is managed by the EPA, and provides information on the agency's mission and objectives. The page is designed for use by the general public to gather information on the agency. It was used to determine the EPA's roles and mission for the survery of stakeholders.

(Friedler, 2006) Friedler, E.; Lahav, O. (2006) Centralised urban wastewater reuse: what is the public attitude?, *Water Science and Technology.* 54(6-7), 423-430.

This peer-reviewed article aimed to elucidate factors affecting support of wastewater reuse through a survey of Israeli urban public, focusing on environmental concerns and public perception of this issue. The survey showed that Israeli public were generally supportive of wastewater reuse. The authors also suggested a list of strategies for managing public perception issues in the implementation of wastewater reuse. This source was used in the report to understand the factors affecting public perception of wastewater reuse.

(Gelt, 1997) Gelt, Joseph (1997) Sharing Colorado River Water: History, Public Policy and the Colorado River Compact. Accessed on October 27, 2006 from http://ag.arizona.edu/AZWATER/arroyo/101comm.html

This article, published by the Water Resources Research Center at the University of Arizona, explains the history of the Colorado River as a water source and the ensuing policy issues between states that use it as a resource. Information from this article is used in the Background section in the Appendix to specifically describe the Colorado River Compact and its historic implications on Nevada.

(Gelt, 2004) Gelt, Josepth (2004) Arizona, Nevada Are Partners in Major Water Banking Deal: Nevada gets water; Arizona gets funds, political ally, *Arizona Water Resource,* Vol 13 No 3. Accessed on November 21, 2006 from http://cals.arizona.edu/AZWATER/awr/novdec04/feature1.html.

Also from the Water Resources Research Center at the University of Arizona, this article provided a fact in the "Benefits and Risks of Water Resource Options" table about interstate water dependencies leading to increased risk of disputes between states. This article explains the water banking agreement between Nevada and Arizona and emphasizes the strengths and vulnerabilities posed to each state through interstate water policies

(Gleick, 1995) Gleick, Peter H.; Loh, Penn; Gomez, Santos V.; Morrison, Jason (1995) California Water 2020: A Sustainable Vision. The Pacific Insitute. Accessed November 15 2006 from http://www.pacinst.org/reports/california_water_2020/ca_water_2020_exec.pdf.

Gleick is a principle researcher at the Pacific Institute, a credible independent research and policy organisation in California. This report develops a "sustainable vision" in order to demonstrate how California can address water issues through efficiency and innovative water management practices. Gleick's work was used as an example of a demand-side approach to water management.

(Grinnell, 2004) Grinnell, G. K.; Janga, R. G. (2004) AWWA Golf Course Reclaimed Water Marketing Survey Results

This was a survey conducted by the American Water Works Association Water Reuse Committee to determine the perceptions and operating issues of golf courses around the U.S. (including Nevada) on the use of reclaimed water. This source provided an insight to the report on the general alignment and attitude of golf course operators on the use of reclaimed water.

(Grinnell, 2006) Grinnell, Gary K. (2006) Personal communication on the golf course reclaimed water marketing survey results. Senior Civil Engineerin, Southern Nevada Water Authority, Las Vegas Valley. December 7, 2006.

Mr. Grinnell was interviewed by telephone to provide further informatIon on the golf course reclaimed water marketing survey results. He provided first-hand knowledge of the views of golf course operators regarding reclaimed water regulations and competitive pricing issues. This information was used to develop the section on perceptions of key commercial customers.

(Hagen, 2000) Hagen, Christoper. (2000) Murky Waters: In River politics, the one thing that's clear is Las Vegas' looming problem, Las Vegas Life. Accessed on November 4 from http://www.lvlife.com/2000/03/features/story02.html.

This article from the Las Vegas Life, an online magazine publication, includes a brief history on water use in Las Vegas, its current struggle to meet growing water demand given its increasing population, and neighboring states' needs. Specifically the report uses article information about conservation efforts in hotels and resorts, as well as a retrofit funding program when potable water is used in decorative water features.

(Harrison and Oakes) Harrison, E. Z., & Oakes, S. R. (2002). Investigation of Alleged Health Incidents Associated With Land Application of Sewage Sludges. *New Solutions, 12*(4), 387 - 408.

This peer-reviewed journal article documents symptoms of illness documented in residents sites where biosolids have been applied to land. It recommends a system of tracking and investigating health incidents near land application sites and suggests that land application of Class B sludges should be eliminated. This paper was provided to demonstrate the controversy that exists around the practice of land application of treated biosolids.

(Hennessey, 2005) Hennessey, Kathleen (2005) Nevada Focus: Water legislation makes little headway, *Las Vegas Sun.* Accessed November 4, 2006 from http://www.lasvegassun.com/sunbin/stories/nevada/2005/apr/21/042110297.html

This article discusses the tension between mining, labor, and urban growth groups and conservation legislation. Specifically, the article mentions the failure of conservation bills due to opposition from these groups, and their efforts to sidestep water scarcity by building a pipeline to the tap northern counties' groundwater. This information is used in the Issue Framing section of the report to illustrate problems around water visioning and also mentioned in the Regulation section.

(Huck et al, 2000) Huck, Mike; Carrow, R. N.; Duncan, R. R. (2000) Effluent Water: Nightmare or dream come true? *USGA Green Section Record*, March / April, 2000. Accessed December 7, 2006 from http://turf.lib.msu.edu/2000s/2000/000315.pdf.

This article was published in the United States Green Section Record, a publication on the maintenance of golf courses. This source provided information on the price differential between reclaimed water and potable water provided to golf courses, which was used to establish the argument in favor of competitive water pricing incentives.

(Hydro Engineering, 2004) Water Recycling: Recycled water key to valley's growth. Hydro Engineering Inc., Salt Lake City, Utah. Accessed, December 7, 2006 from http://www.hydroblaster.com/News6-7-04.htm.

Hydro Engineering is a manufacturing company that provides waste water recycling and filtration equipment. This news article provided information on the rates for reclaimed water across the different municipalities in the Las Vegas Valley. These rates were used to build a case for competitive water pricing strategies as incentives to promote reclamation technology.

(Kayombo, et al., 2005) Kayombo, S., Mbwette, T. S. A., Katima, J. H. Y., Ladegaard, N., & Jorgensen, S. E. (2005). Waste Stablization Ponds and Constructed Wetland Design Manual. Retrieved November 1 2006, from http://www.unep.or.jp/Ietc/Publications/Water_Sanitation/ponds_and_wetlands/index.asp

This document was developed through a partnership between the United National Envrironment Program and the Danish International Development Agency. It outlines general technical and design principles regarding waste stablisation ponds and constructed wetlands. This source was used to demonstrate the potential for constructed wetlands to provide an environmental benefit in wastewater treatment.

(KUED, 2006) KUED. (2006) Desert Wars - Water and the West Extended Interview with Jamie Cruz, Director of Energy and Environmental Services, MGM Mirage. Retrieved November 12 2006, from http://www.kued.org/productions/desertwars/cruz_jamie.php
This is a transcript of an interview on public television with the person responsible for the on-site water reclamation facility at the Treasure Island Resort, which we referenced in the section detailing the implementation of on-site reclamation facilities in Las Vegas.

(Las Vegas Golf, 2006) Las Vegas Golf. (2006). More questions emerge about Billy Walters' golf course dealings. LasVegasGolf.com. Retrieved November 4 2006, from http://www.lasvegasgolf.com/departments/news/more-questions-walters-golf-1522.htm
This article details a scandal surrounding the unusually low price certain golf courses in Las Vegas were paying for reclaimed water. This article contained many facts about the pricing of reclaimed water in the Las Vegas region.

(Lewis, et al, 2002) Lewis, D. L., Gattie, D. K., Novak, M. E., Sanchez, S., & Pumphrey, C. (2002). Interactions of pathogens and irritant chemicals in land-applied sewage sludges (biosolids). *BMC Public Health, 2*(11). Retrieved December 7, 2006 from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=117218.
This peer-reviewed journal article documents adverse effects of residents living close to sites recieving applications of processed sewage. The report notes a prevalence of complaints regarding skin, eye, and respiratory irritation downwind of the land applicaiton sites. It recommends consideration of interactions between the chemicals and pathogens in sewage sludges before application. The report was used to demonstrate controversial aspects regarding land application of biosolids.

(Ludwig, 2006) Ludwig, Art (2006) Greywater Central. Accessed on November 4, 2006 from http://www.oasisdesign.net/greywater/
Art Ludwig is an on-site wastewater reclamation consultant, and his site has a wealth of information on the topic. We referenced him in our sections describing the technologies and requirements involved in wastewater reclamation in section 2.

(LVWCC, 1999) Las Vegas Wash Coordination Committee (LVWCC). (1999). Las Vegas Comprehensive Adaptive Management Plan. Retrieved October 29, 2006, from http://www.lvwash.org/resources/docs/lvwcamp.html
This Management Plan is an authoritative report released by a multi-stakeholder group created to develop recommendations on mitigating environmental impacts within the Las Vegas Wash. The plan makes recommendations to reduce erosion by building control structures, repair natural wetlands within the watershed, and develop alternative discharge locations for reclaimed water. This report was used extensively to categorized the adverse environmental impacts within the Las Vegas Wash, and present the solutions that are being implemented to mitigate environmental issues.

(LVWCC, 2006) Las Vegas Wash Coordination Committee (LVWCC). (2006). Las Vegas Wash Coordination Committee Website. Retrieved October 29, 2006, from http://www.lvwash.org/
The LVWCC website provides information for the public on environmental issues within the Las Vegas Wash, and was used to inform the stakeholder table in section 4.

(LVWCC, 2006a) Las Vegas Wash Coordination Committee (LVWCC). (2006). Las Vegas Wash Coordination Committee Website. Retrieved November 17, 2006, from http://www.lvwash.org/being_done/goals/vision.html
This webpage is maintained by the Las Vegas Wash Coordination Committee, and provides information on the comittee's vision and objectives. It was used to determine the LVWCC's mission for the survery of stakeholders in section 4.

(LVWCC, 2006b) Las Vegas Wash Coordination Committee (LVWCC). (2006) Las Vegas Wash Coordination Committee Website. Retrieved November 30, 2006 from http://www.lvwash.org/wash/wash_images/panoramic_main.html.
The LVWCC website provides information for the public on environmental issues within the Las Vegas Wash. This source was used for a picture of drought levels in the Las Vegas Bay.

(LVWCC, 2006c) Las Vegas Wash Coordination Committee (LVWCC). (2006) Las Vegas Wash Coordination Committee Website - The Study Teams. Retrieved December 4, 2006 from http://www.lvwash.org/being_done/goals/study_team.html.

This website summarizes the four study teams that were developed as a result of the Comprehensive Adaptive Management Plan released by the LVWCC in 1999. The site is part of the LVWCC's main website, which offers authoritative and current information on the progress toward implementing the recommendations of the management plan. This webpage was referenced in order to show how study teams have been formed from the original recommendations produced in the management plan.

(LVVSA, 2000) Las Vegas Valley Study Area: Area Wide Reuse Study. (2000) Clark County, Nevada Official Website. Retrieved December 1, 2006, from http://www.co.clark.nv.us/air_quality/Environmental/WaterQuality/AreaWideReuseStudy.pdf

This study outlines technical and regulatory issues in wastewater system implementation in Las Vegas and is a primary source in the Regulatory and Economic Incentives policy issue section.

(LVVWD, 2006) Las Vegas Valley Water District (2006) Water Waste. Accessed on October 23, 2006 from http://www.lvvwd.com/html/ws_waste.html

This webpage summarizes the current prohibitions on water waste within the Las Vegas Valley area. The information is provided by the Las Vegas Valley Water Distrct, the authoritative agency with regards to water in the Las Vegas Valley. This source was used to demonstrate the level of control excercised over wasteful uses of water, and how these prohibitions create an integrated framework that balances supply- and demand-side issues in order to maximize the benefit of Las Vegas' water resource.

(LVVWD, 2006a) Las Vegas Valley Water District (LVVWD). (2006). Water Rates and Usage Thresholds. Retrieved November 4 2006, from http://www.lvvwd.com/html/cust_serv_rates_thresholds.html

This webpage contains the pricing schedule for potable water as dictated by the Las Vegas Valley Water District, which we used in section 5.4, wherein we describe the pricing of water in the region.

(LVVWD, 2006b) Las Vegas Valley Water District (LVVWD). (2006). Mission, Vision & Values. Retrieved November 17, 2006, from http://www.lvvwd.com/html/about_mission.html

This webpage contains the mission statement of the Las Vegas Valley Water District that we used to inform the stakeholder table in section 4.

(Mays, 2000) Mays, Larry W. (2000) Water Distribution System Handbook: Modern Water Distribution Systems -- System Components. McGraw-Hill. Online version available at: http://www.knovel.com/knovel2/Toc.jsp?BookID=702&VerticalID=0

This reference is an online handbook providing a comprehensive, state-of-the-art guide to water distribution systems and presents detailed coverage of the latest methods, materials, techniques, and tools for water distribution systems for both potable and non-potable networks. We used this text for information around our discussion of water distribution components in our distribution considerations section of the current state.

(McNulty, 2005) McNulty, J. (2005) UCSC desalination project to give cities tools they need to weigh pros and cons. US Santa Cruz: *Currents Online.* Accessed November 21, 2006 from http://currents.ucsc.edu/05-06/07-11/desalination.asp

This article provides a fact in the "Benefits and Risks of Water Resource Options" table in the Current State section around accidentally capturing fish in coastal water intakes as a result of desalination. Specifically, this article discusses the pros and cons of water desalination in California.

(National Academies, 2006) The National Academies. (2006) The National Research Council. Accessed on November 18, 2006 from http://www.nationalacademies.org/nrc/

This National Academies webpage provides information on the National Research Council. This source was used to cite the mission, values and beliefs of the NRC for inclusion in the stakeholder mapping table.

(National Biosolids Partnership, 2006) National Biosolids Partnership (2006) What does it mean to be an NBP Certified Agency? Retrieved November 1 2006, from

http://www.biosolids.org/docs/WhatisNBPCert.pdf
This document is part of the National Biosolids Partnership's internet site. The NBP is a partnership between the National Association of Clean Water Agencies, the Water Environment Federation, and the U. S. EPA. The document provides information on NBP's certification program which audits waste treatment facilities that produce biosolid waste. This source was used to determine that no organisations in Nevada have been certified under the program, and in advancing the idea that a similar certification system for health management issues may be beneficial.

(NDEP, 2004) Nevada Division of Environmental Protection (2004) Notice of Intent to Amend Nevada Administrative Code 445A.275 through NAC 445A.280 Accessed on December 2, 2006 from http://ndep.nv.gov/docs_04/p2004-15_notice.pdf
This notice of intent from the Nevada Division of Environmental Protection outlined amendments to the exisiting "Use of Treated Effluent Regulations" that would expand the use of treated wastewater in a manner consistent with existing regulation. This is mentioned briefly in the Regulation and Economic Incentives section of this report.

(NDEP, 2006a) Nevada Division of Environmental Protection. Accessed on November 17, 2006 from http://ndep.nv.gov/
This website maintained by the Nevada Division of Environmental Protection provides information to the public on environmental issues, various programs NDEP conducts, and upcoming meetings and seminars. This website was used to determine the roles and missions of NDEP for the stakeholder analysis of the report.

(NDWR, 2006) Nevada Division of Water Resources. Accessed on December 3, 2006 from http://water.nv.gov/
This webpage provides Nevada Division of Water Resources' mission statements for use by the general public. It was used to gather information on the NDEP's missions and core beliefs for the survey of stakeholders.

(NRC, 1982) National Research Council. *Quality Criteria for Water Reuse.* Washington, D.C., United States: National Academies Press.
The NRC was commissioned to produce this report on quality criteria for the reuse of water in 1982. It provided a seminal body of work on the issue of water treatment and reuse guidelines. This report has formed the basis for further, more recent NRC studies, and influenced the formation of this report on water reclamation in Las Vegas. It was used extensively in developing the context and rationale around water reclamation practices and technologies for this report.

(NRC, 1994) National Research Council. Water Science and Technology Board (WSTB) (1994) *Ground Water Recharge Using Waters of Impaired Quality*. Washington, D.C., United States: National Academies Press.
This NRC report was commissioned in order to assess the use of waters of "impaired-quality" for ground water recharge. Municipal treated wastewater, storm run-off, and irrigation return flow were the three types of impaired-quality waters assessed. The report concluded that these impaired-qualities waters can be used effectively to enable groundwater recharge. This source was used to assess the previous NRC work on treated wastewater in developing the new contribution of the committee's study; it was also cited to establish the risks posed to human health through inappropriate use and management of reclaimed water.

(NRC, 1998) National Research Council. Water Science and Technology Board (WSTB). (1998). *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies With Reclaimed Water*. Washington, D.C., United States: National Academies Press.
This study, conducted by the NRC, provides information stating that the intentional reclamation of treated wastewater in the U.S. is exclusively for direct non-potable end-use. It also presents information around water quality control strategies around human health, including risk assessment, monitoring, safety testing, and system reliability, and the importance of their demonstration to the public. The study's findings are presented in the Human Health section of the report.

(NRC, 2000) National Research Council. Committee to Review the New York City Watershed Management Strategy. (2000). *Watershed management for potable water supply : assessing the New York City strategy*. Washington, D.C.: National Academy Press.

The NRC was commissioned to perform this study by the City of New York in order to assess the validity of a watershed agreement adopted by the city in 1997. The Council found that the agreement to be a good example of wastershed management, but cautioned that methods for the detection of pathogens need to be improved. This study was cited in the new contribution section of the report to indicate previous reports on water issues commissioned at the municipal level.

(NRC, 2002) National Research Council (NRC). (2002). Biosolids Applied to Land: Advancing Standards and Practices. Retrieved November 1 2006, from http://newton.nap.edu/catalog/10426.html

This NRC report was commissioned to review the methods used to develop EPA's 1993 regulation on land application of bioisolids. The study recognized improvements in assessment practices and scientific knowledge around health and environmental issues in biosolids disposal. It recommended several steps for addressing health concerns, environmental issues, and uncertainties in technical data on biosolids standards. This credible source was cited in order to demonstrate the existence of uncertainty in biosolids disposal, and suggest areas for improvement in addressing health and environmental concerns.

(Onn, 2005) Onn, Lee Poh (2005) Water Management Issues in Singapore. Institute of Southeast Asian Studies, Singapore. Retrieved December 7 2006 from http://www.khmerstudies.org/events/Water/Lee%20Nov%202005.pdf.

Onn provides a summary of water management practices in Singapore, which faces a constrained water supply and heavy reliance on Malaysia to meet its needs. This report was presented for peer review at a conference in southeast Asia in December, 2005. It is cited as an international study in order to fix the current state of literature on wastewater reclamation issues for the new contribution section.

(Okun, 2000) Okun, D. A. (2000). Water Reclamation and Unrestricted Non-potable Reuse: A New Tool in Urban Water Management. *Annual Review of Public Health, 21*(1), 223-245.

Okun provides a comprehensive review of water reclamation issues in this peer-reviewed journal article for *Annual Reviews*. He provides an overview of different levels of reclaimed water practices throughout the world, and a general exploration of major issues in reclamation. This article was used to establish the state of current literature on wastewater reclamation, and guided the committee's determination of the new contribution provided by its study of Las Vegas.

(Parker, 2006) Parker, Stephen (2006) Director of the Water Science and Technology Board, National Research Council. Personal communications during initial development of scope and after review of draft executive summary. September 14; November 16, 2006.

Dr. Stephen Parker is Director of the Water Science and Technology Board at the National Research Council. He provided expert insight into current issues in water reclamation issues, and guided formation of the committee's initial proposal for the scope of work in this study.

(Patton and Sawicki, 1993) Patton, C. V., & Sawicki, D. S. (1993). *Basic methods of policy analysis and planning* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

In this book, Patton and Sawicki provide a basic overview of methods for analyzing policy issues and policy-based decision-making. The committee used this text to develop its rationale for using issue framing tools to develop an overarching vision for water management strategies.

(Pharino, 2006) Pharino, Chanathip (2006) Postdoctoral Associate, MIT Sea Grant Program. Personal communication following review of draft executive summary. November 16, 2006.

Dr. Pharino is an MIT PhD graduate and an expert in water resources, having completed her PhD dissertation on water trading issues. She is currently working as a postdoctoral associate in MIT Sea Grant program. Dr. Pharino provided valuable feedback on the report (though the executive summary provided to her) in a 90-minute personal interview.

(Po, 2004) Po, Murni; Kaercher, Juliane; Nancarrow, Blair E. (2004) Literature review of factors influencing public perceptions of water reuse, Australian Water Conservation and Reuse Research Program

This Australian report conducted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) provides a comprehensive study on public perception issues in water reclamation, including international case studies of successes and failures, factors affecting public perception, and strategies to overcome barriers. This source was used extensively to provide background information on public perception issues of water reclamation in Section 5 of the report.

(Robinson, 2005) Robinson, K.G.; Robinson, C. H.; Hawkins, S. A. (2005) Assessment of public perception regarding wastewater reuse, *Water Science and Technology,* Vol 5 No 1 pp 59-65

This peer-reviewed article is based on a survey of metropolitan population in Southeast U.S. conducted by researchers from the University of Tennessee on their perception and level of knowledge on water reclamation issues. This article provided information on factors affecting public perception in water reclamation in Section 5 of the report.

(Roessler, 2006) Roessler, Christina (2006) Las Vegas and the Groundwater Development Project: Where does it start? Where does it end? A Progressive Leadership Alliance of Nevada (PLAN) Report. PLAN: Las Vegas, United States.

This study, commissioned by the Progressive Leadership Alliance of Nevada, studies the implications of the proposed SNWA pipeline to tap the groundwater resources of the counties to the North of Las Vegas. The study illustrates the potential hazards of this strategy both environmentally and economically, and the report uses cost estimates from the study in the section of the Current State that discusses groundwater development.

(Ruzicka, 1996) Ruzicka, D. (1996) Challenges to Balancing Conservation with Supply in Integrated Resource Management. *Journal of Contemporary Water Research and Education,* Vol 104, p 15. Accessed November 21, 2006 from http://www.ucowr.siu.edu/updates/pdf/V104_A4.pdf.

This article provided a fact in the "Benefits and Risks of Water Resource Options" in the Current State section around the challenges of quantifying demand-side water conservation savings. The article discusses Integrated Resource Planning as a strategy involving equal consideration from both supply and demand-side risk options.

(SNWA, 2006a) Southern Nevada Water Authority (SNWA): 2006 Water Resource Plan, 2006. Accessed on November 2, 2006 from http://www.snwa.com/html/wr_resource_plan.html

This document is Southern Nevada's comprehensive plan for water resources in the region. It details the region's anticipated demands for water, and the future supplies. This was a highly useful document, and we used throughout the report. The Southern Nevada Water Authority is the central official authority, and as such, is highly credible.

(SNWA, 2006b) Southern Nevada Water Authority (SNWA): 2006 In-State Resources Brochure. Accessed on November 4, 2006 from http://www.snwa.com/html/wr_instate.html

This webpage details the water resources, and appropriate conservation measures underway that the Southern Nevada Water Authority has identified in its region. We used this resource to inform our exploration of the current water resource situation throughout section 2

(SNWA, 2006c) Southern Nevada Water Authority (SNWA): 2006 Concepts for Development of Additional In-State Resources. Accessed on November 4, 2006 from http://www.snwa.com/html/wr_instate.html

This webpage describes the Southern Nevada Water Authority's options for developing new sources of water in-state. This information was used in section 2 to explain how Las Vegas is planning on increasing its water supply to meet anticipated demand.

(SNWA, 2006d) Southern Nevada Water Authority (SNWA) (2006) Drought. Accessed on November 4, 2006 from http://www.snwa.com/html/drought_index.html

This webpage describes the Southern Nevada Water Authority's response to drought conditions in the region, and how effective those measures have been. We used this information in section 2 when describing the drought situation in Las Vegas.

(SNWA, 2006f) Southern Nevada Water Authority (SNWA) (2006) Southern Nevada Water System. Retrieved November 4 2006, from http://www.snwa.com/html/about_snws.html.

This site, located within the main website of the Southern Nevada Water Authority, discusses the Southern Nevada Water System (SNWS) and its history. The site describes the role of the Colorado River Commission alongside federal Bureau of Reclamation in conceiving, planning, and financing the SNWS. This information is mentioned in the History of the Las Vegas Water Supply section, located in the Appendix of this report.

(SNWA, 2006g) Southern Nevada Water Authority (SNWA) (2006) History of SNWA. Retrieved November 4 2006, from http://www.snwa.com/html/about_history.html.

Located within the main website of the Southern Nevada Water Authority (SNWA), this page discusses the history of the SNWA, as well as briefly mentioning its current role as operator of the Southern Nevada Water System. This information is used in History of the Las Vegas Water Supply section, located in the Appendix of this report, to discuss the SNWA's historic role in Las Vegas' water management.

(Stapleton et al, 2001) Stapleton, Phillip J.; Glover, Margaret A.; Davis, Petie S. (2001) Environmental Managment Systems: An implementation guide for small and medium-sized organizations. National Science Foundation International. Retrieved December 4, 2006 from http://www.epa.gov/owm/iso14001/ems2001final.pdf.

This document summarizes the methodology of Environmental Managment Systems, which is a framework for management of environmental impacts that is recommended by the committe in this study of Las Vegas. This report was published by NSF International through a collaboration with the U.S. EPA's Office of Wastewater Management and several other offices. It was cited with reference to EMS as an appropriate tool for management of envrionmental impacts from disposal of biosolids produced at wastewater management faciltites.

(State of Nevada, 2006) State of Nevada (2006) Nevada Administrative Code, Chapter 445 Sanitation, Sections 275-280: The Use of Treated Effluent for Irrigation. Accessed on November 27, 2006 from http://www.leg.state.nv.us/nac/NAC-445A.html#NAC445ASec275

This website provides the Nevada Administrative Codes for Water Controls; specifically codes 445A.275 - 445A.280 are outlined in the State Regulation section of the Regulation Issues and describe guidelines to protect Nevada's waters from pollutants and safeguard public health.

(Stave, 2003) Stave, K. A. (2003) A systems dynamic model to facilitate public understanding of water management options in Las Vegas, Nevada. Journal of Environmental Management 67 (2003) 303–313.

This journal article provides information in the Current State section on average annual water supply resources in Las Vegas, including a graph showing projected supply and demand, as well as estimates of outdoor water usage in the Las Vegas area.

(Toze, 2006) Toze, S. (2006). Water reuse and health risks -- real vs. perceived. *Desalination, 187*(1-3), 41-51.

This peer-reviewed journal article discusses the health risks of water reclamation treatment, and warns that overtreatment can drive up the costs of advanced watertreatment facilities. It also identifies the risks posed by pathogens and uncertainties in current methods of treating wastewater. This source was cited alongside other studies in order to develop the table of uncertainties and safeguards in the health section of the committee's Las Vegas study. It was additionally cited to support the argument that high costs of treatment at advance water treatment facilities can constrain the viability of these projects.

(UNLV, 2006) University of Nevada, Las Vegas (2006). Center for Business and Economic Research: Economic Trends and Forecasts for Nevada. Accessed on November 8, 2006 from http://www.unlv.edu/centers/cdclv/healthnv/economy.html.

The Center for Business and Economic Research at the University of Nevada, Las Vegas, work together to create a long-term forecast of several economic and demographic characteristics of Clark County, including population. This website provided statistics for population growth as well as population projects up to 2035.

(Venema, 2006) Venema, Hank (2006) Director of Natural Resource Management and Security, International Institute of Sustainable Development. Personal communication concerning description of project scope and focus on water reclamation. November 1, 2006.

Dr. Venema is a respected engineer and researcher at the International Institute of Sustainable Development in Winnipeg, Canada. He was contacted in light of his current research involving water management issues in the province of Manitoba, Canada. Dr. Venema provided insight into the overarching view of sustainability and demand-side oriented approaches to water management. Additionally, he provided initial feedback on the findings and results of this report.

(Weigel, 2006) Weigel, A. (2006). Technology and Policy Analysis. Class notes for Introduction to Technology and Policy. Cambridge, United States: Massachusetts Institute of Technology.

This analysis framework, presented in the course ESD:10, *Introduction to Technology and Policy*, is used extensively as a report structuring methodology in addition to the "Policy Toolbox" used to analyze technology and policy interactions. Used in each policy issue section within this report, adoption of this framework allowed considerations of issue framing, stakeholder analysis, technology enabling policy and vice versa. Also, an examination of the powers, windows, and channels as presented in the framework allowed a thorough analysis of the best practices and recommendations in the Conclusion section of this report.

(WRA, 2003) Water Resources Authority (2003) Smart Water: A Comparative Study of Urban Water Use and Efficiency Across the Southwest. Accessed on November 4, 2006 from http://www.westernresourceadvocates.org/media/pdf/SWAppendixB.pdf, p. 147.

This study, published by the Water Resources Authority, a non-profit environmental law and policy organization dedicated to restoring and protecting the natural environment of the Interior American West, outlines the conservation-based landscaping ordinances that affect water use in Las Vegas. This information is presented in the Public Perception section of the report to assess golf course operators perceptions.

(WRF,2006) Water Reuse Foundation (2006) Project Profile on An *Economic Framework for Evaluating the Benefits and Costs of Water Reuse*. Project Number WEF-03-006.

This project profile document provides the main economic considerations in evaluating the benefits and costs of water reuse. This was briefly summarized in the Introduction section of the report, where it was explained that this topic has not been included in the report.

(WRRIC, 2006) Water Reclamation and Reuse Information Center: Public Perception, 2006. Accessed on November 4, 2006 from http://www.soe.uoguelph.ca/webfiles/khosrow/wrric/Perception/DWPLA.htm

This University of Guelph Water Reclamation and Reuse Information website provides a wealth of information on water reclamation, including background, perception, health, regulatory and technological issues. This website was used in the report to provide an example of how the lack of a public perception management strategy had led to the failure in the implementation of a wastewater reclamation system in California.

(Yari, 2005) Yari, Paula F. (2005) Water Reuse – A Water Supply Option in the Metropolitan Atlanta Area? Proceedings of the 2003 Georgia Water Resources Conference.

This paper explored several approaches to wastewater reclamation under consideration in Atlanta. We used this facts from this paper to inform our analysis of the unplanned indirect potable reuse in section 2.5.

(Young, 2003) Young, Samantha (2003) Las Vegas Water - Feds warn of tapping out supply: Valley among points of concern on Interior Department 'conflict map'. *Review Journal*, Saturday, May 3, 2003. Retrived December 4, 2006 from http://www.reviewjournal.com/lvrj_home/2003/May-03-Sat-2003/news/21244689.html.

This newspaper article was used to corroborate the Bureau of Reclamation's 2003 Water 2025 study report. The article specifically identifies Las Vegas as an area of concern that is vunerable to water shortages in the future.

Appendix 1: History of the Las Vegas Water Supply

The history of water use in Las Vegas is characterized by limited access to water resources and a lack of infrastructure to distribute water to a rapidly growing population. While original reliance on groundwater sources successfully met water demand, the expanding area eventually developed a need to utilize water from the Colorado River. Presented with challenges around providing river water, the federal government has at times intervened to finance public works projects such as the Hoover Dam and Las Vegas' current water system. Today, water supply continues to be constrained by exponential population growth and limited access to water resources, including the Colorado River.

In 1922, the Colorado River Compact (CRC) established the Lower Colorado River Basin apportionment in response to concerns by neighboring states that California's growing population would claim a disproportionate amount of Colorado River water (Gelt, 1997). The CRC specified water allotments between Arizona, California, Nevada at 2.8 million, 4.4 million, and 300,000 acre-feet per year. Due to its small population, lack of agricultural industry, and seemingly abundant supply of spring water, Nevada was content with its relatively small portion of water from the CRC (SNWA, 2006a).

In the 1930s, the federal government built the Hoover Dam as part of a nationwide effort to expand rural access to electricity. The construction resulted in the creation of Lake Mead, but this abundant new water source could not be utilized due to an absence of infrastructure, and groundwater use consequently continued to dominate as a local water source in Las Vegas (SNWA, 2006a).

The first company to start using Colorado River water provided by Lake Mead to support industrial operations was Basic Management Inc. (BMI) (SNWA, 2006a). Combined with the establishment of the federal Nellis Air Force Base in Las Vegas, each of these projects sent a great deal of federal dollars into the local economy, and resulted in a doubling of the local population during WWII. With the influx of business and residents during the war years, the stage was set for the modern resort industry.

Following the war, the Nevada state legislature created the Las Vegas Valley Water District in 1947 (LVVWD), which acquired the original water rights of the Las Vegas Land and Water Company (SNWA, 2006a). Recognizing the uncertain capacity of groundwater, the LVVWD negotiated with the BMI complex in the mid-1950s to extend its existing water pipeline from Lake Mead to serve residents and businesses. Efforts to facilitate this transition to Colorado River water were led by the Nevada Division of Water Resources (NDWR), overseen by the State Engineer of Nevada.

Over the next two decades the growing population, combined with a lack of local funds, led to federal financing of the Southern Nevada Water System (SNWS) (SNWA, 2006a). Working closely with the federal Bureau of Reclamation, the Colorado River Commission completed the SNWS project in 1982 (SNWA, 2006a).

Ultimately the Southern Nevada Water Authority (SNWA) was formed in 1991 to consider water issues on a regional basis (SNWA, 2006g). Comprised of seven districts and cities around Las Vegas, SNWA's primary responsibility was to identify, acquire, and manage Southern Nevada water resources (SNWA, 2006a). Following the consolidation, the federal government transferred ownership of SNWS water facilities to the SNWA in 2001 (SNWA, 2006g).

From 1970 to 2004, the population of the Las Vegas metropolitan region, loosely defined as Clark County, has grown from 300,000 to over 1.7 million people, at an average yearly rate of 7% (SNWA, 2006a). It is the fastest growing region in the U.S., and the Clark County Comprehensive Planning Commission expects a peak population of 3.5 million people in 2035 (UNLV, 2006). Accurate estimates of water demand, however, have been historically difficult for the Las Vegas area due to extremely conservative estimates of population growth, and preparing for future water uncertainty is key to Las Vegas' sustainability. The actual historical growth in Las Vegas' water use is shown in Figure 12, which illustrates the exponential rise in water demand over the last 50 years.

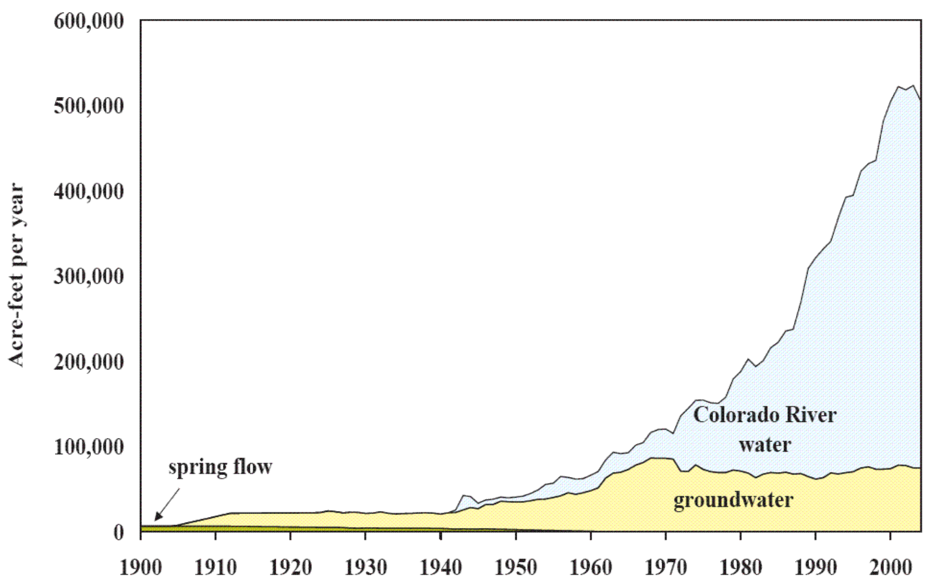


Figure 12: Historical water withdrawals from the Colorado River and in-state groundwater reserves, 2004 (SNWA, 2006a)